A
LABORATORY MANUAL
FOR THE SOLUTION OF
PROBLEMS IN BIOLOGY

BY

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"To know nature and man is the sum of all earthly knowledge."

— G. Stanley Hall.

"The work of the high school should have for its central aim the helping of pupils to be helpful in the home and community *here* and *now*. . . . Every bit of science and every bit of literature should be taught with such ends in view."

— A. W. Baldwin.

"Half a million lives are cut short and five million people are made ill by preventable diseases each year. With universal knowledge of ***hygiene*** and *sanitation* nearly all deaths from such causes could be prevented."

— Household Education League.

sharpe's laboratory manual.
w. p. 1.

PREFACE

Most teachers of biology in secondary schools to-day aim to emphasize the biological relations of plants and animals from a physiological standpoint. The practical aspect is also becoming more and more recognized as most desirable, as opposed to the strictly educational and cultural functions of this subject. Moreover, it is being gradually brought to our attention that methods of study that induce *thinking* are of far more import than any attempts at mere memorizing.[1] Hence we have what may be called the "Problem Method" of study and class exercise.

With these considerations in mind, I have attempted to develop a series of solutions of problems in biology. These problems are intended to be primarily *physiological* in their import, but with especially significant references made to man at every opportunity. I am confident that this method of treatment will not be interpreted as being too utilitarian, although the relations of plants and animals to man are by no means lightly dwelt upon. "Of all the pleas that Spencer[2] makes for the sciences, that for physiology is the most convincing, for the problems of hygienic living are always personal and persistent, as are those that pertain to food, stimulants, narcotics, clothing, and shelter. . . . Consequently, the teacher is to be pardoned if he urges the practical, rather than the strictly educational, function of this study."[3]

It appears to be generally admitted that a course in secondary school biology should include training in logical think-

[1] See McMurry, *How to Study*, Chaps. III–VII, for splendid treatment of this phase of educational processes.

[2] *Education*, Chap. I.

[3] De Garmo, *Principles of Secondary Education*, p. 87.

ing and exactness, orderly and neat procedure, general culture, etc. At the same time it seems to be expected that we should include references to food, clothing, shelter, health and sex hygiene, morals, and æsthetics. Such a combination is not impracticable, and yet there does not seem to exist any method whereby such matters may be handled as *problems* in our secondary schools. The attempt to work out such a method has supplied my immediate motive for compiling this book.

Some special arrangements of matter should be noted: First, the solutions are mostly provided with questions and special reports for both class and home work. Second, a list of references for the special reports is added, commonly to topics of human interest not to be found in the ordinary texts in biology. It is suggested that pupils be encouraged to be constantly on the lookout for pertinent articles on biological topics such as may be found in good magazines, the better daily papers, etc. These should be culled and card catalogued. Constant reference is also made to Hunter's *Essentials of Biology*, a volume which this manual is especially intended to accompany. Third, the larger type indicates matter which is regarded as most important. Teachers are expected to cull that which fits the problems nearest at hand. No classes can be expected to cover all the ground outlined in one year. The smaller type indicates matter which is supplementary and optional, depending on the locality, material on hand, and special interests of both teachers and pupils. Much matter is also included to permit abler and more advanced students to choose work that is not being regularly undertaken by the entire class.

Many new texts and manuals have been freely consulted in preparing this manual. Special thanks are due to Dr. W. H. Eddy and Mr. C. W. Hahn of the High School of Commerce, New York, Dr. H. E. Walter of Brown University, Miss A. P. Hazen of the Eastern District High School, New York, and Mr. G. W. Hunter of the De Witt Clinton High School for many helpful suggestions concerning the manuscript; to

Dr. Irving Fisher of Yale University, the American School of Home Economics of Chicago, and the *Journal of the American Medical Association* for certain food studies; to the Merchants' Association of New York for material concerning the house fly; to Dr. W. H. Allen, Secretary of the Bureau of Municipal Research of New York for suggestions and certain statistics concerning infant mortality; to Mr. J. J. Schoonhoven for the loan of several cuts; and to my wife for much assistance with the many details of construction. Constructive criticisms and suggestions for improving this manual will be most cordially welcomed.

R. W. SHARPE.

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NEW YORK.

"The present trend of education seems to be to make these three subjects — the home, agriculture, and industry — the basis of universal, democratic education."

SUGGESTIONS FOR USING THIS MANUAL

Observations. — In the first place, pupils of first or second years in secondary schools have too limited an experience to permit of their being left to their own devices. All observations, therefore, should be made in *small installments* as immediate answers to certain leading questions which pupils should be encouraged to ask for themselves. Pupils are to be graded on their *ability* to *see*, at the *time* they *observe*, and as *orally expressed*. "Seeing true means thinking right. Right thinking means right action. To bring about right action is the end of Science. Lack of precision in action is the greatest cause of human misery, for misery is nature's protest against the results of wrong conduct." Optionally, at times, their observations may be written before being orally expressed. Other pupils may be encouraged to criticise any incomplete or wrong observations, until it is evident to all that the necessary observations are as carefully and completely made as is possible with the facilities at hand.

Conclusions. — All pupils are now to write out their *own* conclusions, as based on the observations made. (Optionally they may be recited, depending on the matter under consideration.) A limited time is given in which to write their conclusions, then a number read and criticised until the class individually and as a whole grasps the significance of the observations made and the logical deductions therefrom. Such conclusions are also to be graded at the time, thus bringing about much closer supervision of the work than would otherwise be possible, and with the added and very important advantage of avoiding much of the senseless clerical drudgery of looking over notes. Mistakes are thus corrected at a time when such corrections are the most effective.

CONTENTS

Optional problems are indicated by a star (*).

ADAPTATION FOR RESPIRATION AND EXCRETION

NERVES AND THEIR CONTROL

PERSONAL AND CIVIC HYGIENE

DIRECTIONS TO THE STUDENT FOR KEEPING NOTES IN BIOLOGY

Notebooks are to be brought to every biology period. The notebook, when completed, should contain a record of your daily work, not only the exercises performed in the laboratory, but all home experiments, field excursions, and any other work that is your own original observation. The notebook should *not* contain any copied drawings, dictation notes, or other matter not original with you, unless you specify that *such work was copied.* The *authority* from which such copied work is taken should also be noted.

Exercises written in the laboratory should be written on the ruled paper provided; drawings should be placed on the unruled paper. One side of the paper only may be used, except in the case of home work written in ink, in which event both sides of the paper may be used.

Use a well-sharpened hard pencil (HHHHH) for all drawings made in the laboratory.

Prepare your papers for notes, drawings, and experiments according to the model forms given you in the pages following.

Place your name, class number, the date, and the title of the exercise in the spaces reserved for this purpose on each sheet of paper used. Place also your name, the date, and the title on every piece of home work handed in to the teacher for correction.

Number the notes, answers to questions, or any written paragraphs to the left of the vertical line. Number the pages of all your work, and keep dated work in the proper order before handing it in to be criticised by the teacher.

Especial care should be taken with your drawings. Your hard pencil should be sharpened to a needle-like point. Many

drawings are rejected simply because the pencil was too dull for you to bring out the structures you wanted to show. Every line you make on the paper should mean something. Draw with a firm, bold, continuous stroke. Do not sketch. Do not try to shade, unless you are an artist.

Use the scale indicated in your laboratory directions: thus $\times 2$ means that your drawing is to be made twice natural size. Learn to use the metric system in making your estimates of distance, weight, etc.

Above all things be accurate, careful, and neat. Fifty pages of notes and drawings carefully prepared are worth more than one hundred placed carelessly or hastily on the pages. Your laboratory exercises are in part a training for more accurate and careful science work in the later years of the high school and in college. This is the time and the place for you to learn how to do scientific work, and scientific work is synonymous with accuracy and carefulness.

Date	Title of Laboratory Exercise	Name of pupil

In this space you should place all written observations made in the laboratory. This includes all notes and answers to questions; the questions and directions, however, should under no circumstances be written, they are simply for your guidance. In the space between the two red lines to the left of the page should be placed the number of the answered question. Do not place any drawings on this ruled sheet. This paper may also be used for all home work, accounts of excursions, etc.

Date	Title of Drawing	Name of pupil

Place your drawing or drawings in this space so as to make a symmetrical arrangement. If only one drawing is made, then place it a little to the right of the middle of the page, remembering that about an inch of the left edge of your page is lost in the binding together of the sheets.

Every part of the drawing should be named by means of a series of labels. Indicate each part or structure that you wish to call attention to by means of a broken line running from the part to be labeled outward on the paper outside the drawing. At the outer termination of this line place either a number or a letter which will be repeated in the index below and which will there serve to identify the part shown in the drawing. Indicate exactly where the other end of the dotted line ends by a tiny cross.

The index or table of contents at the foot of the page should be neatly printed; if possible, an equal number of figures or letters should be placed on each side of the vertical line which divides the index into a right and left half. If the number of parts labeled in the drawing is unequal, then the last or odd label should be placed in the space at the bottom of the dividing line, thus insuring a neat and symmetrical page.

Index or Table of Contents

Date	Title of Experiment	Name of pupil

Problem. — State here exactly the question you are trying to solve.

Method. — In this space place all the data with reference to setting up the experiment. Describe all the apparatus used, how you put it together, and how you made use of each part.

Observations. — In this space you should place all observations made upon the experiment from the time of beginning to the time of ending the experiment. If the experiment takes several days to complete, it will probably be necessary to record your observations in a pocket notebook in rough form and later copy it in this space. All details should be put down at the time the observations are made; do not wait until a later time to write up the details, which may easily be forgotten and which may affect the accuracy of the observations you have made. Be sure to indicate in your written notes any unusual occurrences which might influence the final results of the experiment. Such might be a sudden drop in temperature, the drying of seeds, etc.

Conclusions. — In this space place your statement of the solution of the problem you have been working upon. This conclusion should be stated in concise, scientific terms. Be sure you understand your problem exactly before you attempt a solution; this may take considerable time and thought on your part.

Date	Title of Experiment	Name of pupil

In this space should be placed a drawing of the apparatus set up at the beginning of the experiment.	In this space should be placed a drawing showing your apparatus at the completion of your experiment. Be careful to show all changes which take place in the appearance of the materials used in this as compared with the first stage of your experiment.

Index or Table of Contents

THE NATURE AND NEEDS OF LIVING MATTER

PROBLEM I

A study of the common elements in the environment of living things.

a. Nitrogen (N) and the Composition of the Air

Note.—The most abundant elements in living matter are carbon, hydrogen, oxygen, and nitrogen.

Apparatus. — Large deep dish of water, bell jar or large wide-mouth bottle, large cork, and phosphorus.

Method. — Cut off a bit of phosphorus as large as a pea, and float it on the large piece of cork. Ignite it, and cover it quickly with the bell jar.

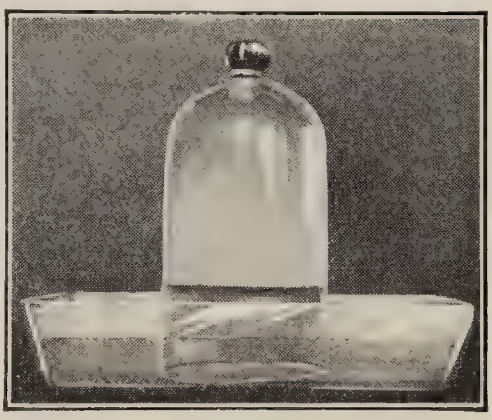

FIG. 1. — Getting the percentage of nitrogen in the air.

Observations. — 1. Does the water rise in the bell jar? If so, how high?

2. What was in the bell jar as it was inverted over the phosphorus?

Note. — The phosphorus unites in burning with an element in the air called oxygen, and forms a substance (fumes) which dissolves in the water present.

Conclusions. — 1. What formerly occupied the space now filled with water? What part of the original contents of the jar was oxygen?

2. If the phosphorus used all the oxygen in burning, about what part of the air must be oxygen? (The rest is mostly nitrogen.)

3. Does nitrogen support burning (*combustion*)?

Note. — The air is composed mostly of oxygen and nitrogen, plus small amounts of water vapor, carbon dioxide, argon, etc.

b. Oxygen (O) and Oxidation

Apparatus. — Test tubes, potassium chlorate, black oxide of manganese, alcohol lamp or Bunsen burner, bent glass tube, 1-holed rubber stopper to fit test tube, wide-mouth bottle, dish of water.

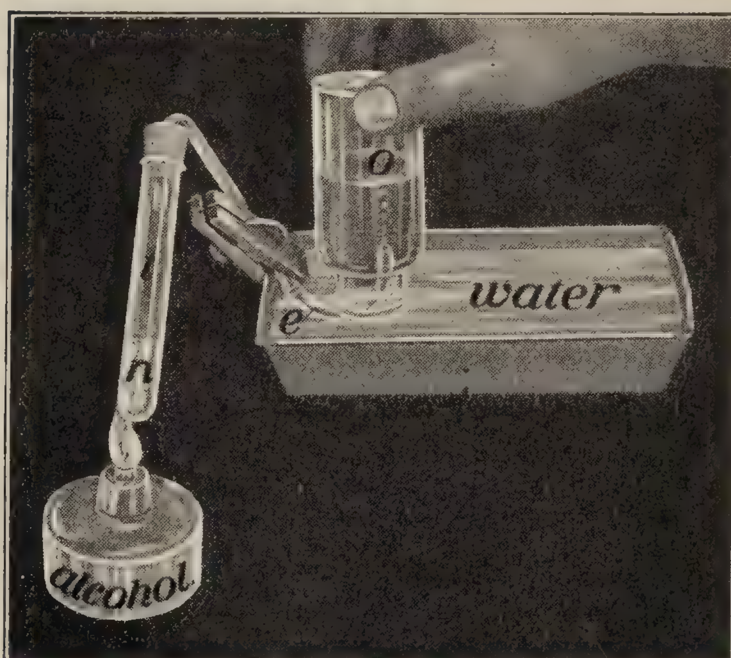

FIG. 2. — Making and collecting oxygen. *t*, test tube; *e*, delivery tube; *n*, chemicals; *O*, oxygen collecting.

General Method. — Heat half a teaspoonful of the chlorate ol potash with slightl less than the sam amount of black oxid of manganese. Th resulting gas may l collected over wate as indicated in Figur 2, or the tests may b made in the test tube in which the oxyge is made.

Method a. — Light splinter of wood, bl out the flame, but see that the end is still glowing. Plun the glowing end in a test tube in which oxygen is being free.

Observations. — 1. What happens to the glowing coal?

2. What difference between the burning of the splinter air and in oxygen?

Note. — When oxygen combines with any substance, heat is always released. The process is named *oxidation.* The substance with which the oxygen unites is said to be *oxidized.* The element or substance oxidized in this case is carbon.

Conclusions. — 1. How could you determine the presence of oxygen in some substances?

2. How account for any differences in the oxidation of the splinter in air and in oxygen?

Note. — The burning of the splinter, accompanied by flame, is an example of *rapid oxidation* or *combustion.*

Method b (*Home Exercise*). — Place an iron nail in a small bottle filled with water. Cork and seal the bottle. Place another iron nail in a shallow vessel containing a little water. Examine the nails from time to time. Which nail is most exposed to oxygen?

Observation. — Which nail has changed in appearance the most? In what way?

Note. — The rusting of iron neans its union with oxygen to orm iron oxide, etc. Since no lame is present, this is an exmple of *slow oxidation.*

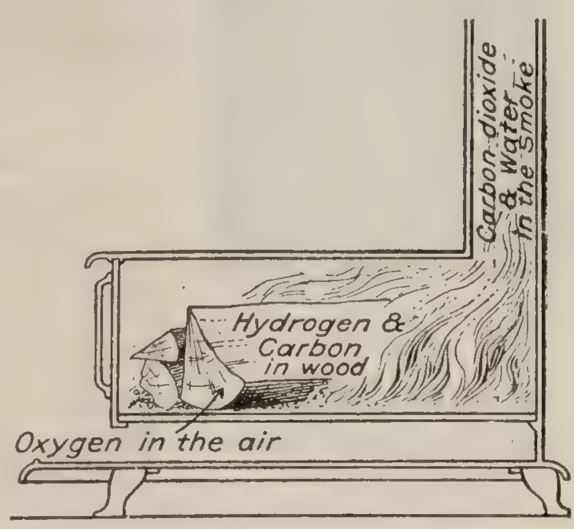

FIG. 3. — Diagram of rapid oxidation or combustion in a stove.

Conclusions. — 1. What is the process of rusting?

2. If heat is one result of oxidation, where does the heat of your body come from? Is his rapid or slow oxidation? eat is a form of *energy.* Why idize coal in a locomotive furnace?

3. What is the relation between rapid oxidation and the lease of energy? Would slow oxidation be satisfactory in locomotive? Is rapid oxidation necessary in our bodies? xplain.

c. Hydrogen (H) (Optional)

Note. — This element is present in all foods, and composes two thirds of water by volume.

Apparatus. — Iron nails or tacks, weak sulphuric acid, wide-mouth bottle, small glass tube drawn to a point and placed in a 1-holed rubber stopper that fits the bottle.

Method. — Put some nails or tacks in the bottle and cover them with the weak sulphuric acid. Insert cork and delivery tube as in Figure 4. Permit the gas to escape for a short time, wrap the bottle in a cloth, and try igniting the escaping gas.

FIG. 4. — Making hydrogen. *w*, cup half filled with water, as a condensing agent.

Note. — The iron pushes off a gas (hydrogen), which was a part of the acid. It appears as bubbles and passes out of the glass tube.

Conclusions. — 1. Does hydrogen burn (oxidize)? What is the result?

2. What collects on a tin cup half filled with water held at the top of the flame?

3. With what does hydrogen unite when it burns?

4. What is the result of this union?

d. Carbon (C) and Carbon Dioxide (CO_2)

Apparatus. — Piece of wood charcoal, soft coal, clay pipe, shavings, clay, alcohol lamp or Bunsen burner, wide-mouth bottle, limewater, sugar or starch, test tubes.

Method a. — Put some bits of wood in the clay pipe and closely cover them with the clay which has been wetted to form a pasty cover, and heat the pipe very hot for a few minutes. Try to light any gas that may issue from the stem of the pipe.

Observations. — 1. What is the color of carbon in charcoal? Is the carbon in the pipe like that in the charcoal stick?

2. How does the carbon separated out in the pipe compare with that in the charcoal stick?

3. What happened when a lighted match was held where the gases were escaping?

Note. — Gas for lighting houses was formerly made in a similar way by heating soft coal in iron boxes.

Conclusions. — 1. What is one of the elements in wood?

2. How does carbon differ from oxygen?

Method b. — Heat some sugar and some starch in separate test tubes. What results?

Conclusions. — 1. Do they contain carbon? Reasons?

2. What do you think is indicated when certain foods are scorched?

3. Name some foods that you think must contain carbon.

4. How, do you infer, does the human body obtain a supply of carbon?

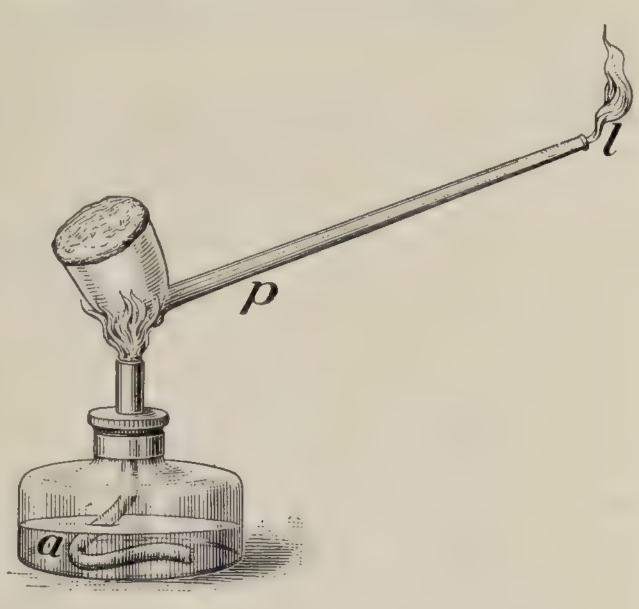

FIG. 5. — Separating wood into gas and charcoal (carbon). *p*, clay pipe containing bits of shavings and covered with wet clay; *l*, flame made by lighting the gas as it issues from the stem.

Method c. — Burn a bit of charcoal (carbon) in the wide-mouth bottle, then add two spoonfuls of limewater and shake the bottle.

Observations. — 1. Is the carbon entirely consumed?

2. Is there any change in the limewater?

Note. — It is known that nothing but *carbon dioxide* will cause limewater to become milky. Carbon dioxide is formed by a chemical union of carbon with *oxygen*. It is really an oxide of carbon. (See Prob. I, *b*, for further notes.)

Conclusions. — 1. How is carbon dioxide formed?

2. What is the test for the presence of carbon dioxide?

Method d. — Breathe through a tube into some limewater. Result?

Conclusions. — 1. What do you decide must be one of the substances that comes from the lungs? Reasons?

2. How must this substance have been formed?

3. What must be one of the elements in the human body?

Questions

1. Can you think of any advantage in the presence of nitrogen in the air?

2. If nitrogen can be obtained from the air only by certain plants, how must animals get it?

3. What part of the air is oxygen? Nitrogen?

4. What are the most abundant elements in living matter?

5. Where may carbon be found?

6. What results from the electrolysis of water?

7. Why does excluding air from a fire cause it to go out?

8. What is the object of a draft in furnaces?

9. Why does a blacksmith use a bellows in forcing air (oxygen) into the fire?

10. Why do we breathe more rapidly when we run or work hard?

11. Try to explain what happens when you strike a match.

Note. — The head of the match contains phosphorus, sulphur, etc.

12. What method did the savages formerly use in starting a fire? Explain.

13. If oxidation also produces energy, or the ability to do work, where does the energy of the locomotive come from? Of the body?

14. How is the body supplied with fresh portions of carbon?

15. How would you test for the presence of carbon dioxide?

16. Sum up as many results of oxidation as you can.

Special Reports[1]

1. The importance of water to living things.
2. The manufacture of charcoal and illuminating gas.
3. The chemical elements in the body.

[1] Instead of having such reports always read in class, let the pupil give a talk on his chosen topic. Such talks should, of course, be carefully thought over beforehand. This gives very good practice in oral presentation. Optionally, written reports may be handed in at times.

PROBLEM II (Optional)

Are mineral matter and water present in living things?

a. Mineral Matter

Method. — Light a splinter and let it burn up as completely as possible.

Observations. — 1. What part of the wood have you learned is oxidized in burning?

2. Is there any portion not oxidized, or left behind as a solid, during the process? What is this substance commonly called? *Note.* — This consists of mineral matter.

3. Burn a piece of meat in a test tube. What remains that will not burn?

Note. — Nearly one half of bone is made of compounds of lime. More than a teacupful of common salt is distributed throughout the body. Enough iron to form a piece as large as a copper cent is found in the blood, liver, and hair.

4. Burn some loam or humus in a test tube. Result?

Conclusions. — 1. What may be found in living things?

2. What do you think is at least one use of the mineral matter in an animal body?

3. Where do you think plants get their mineral matter? Where do animals get theirs?

b. Water

Method. — Weigh a piece of meat, an apple, and a potato. Peel the apple and potato. Put all in a place where they will thoroughly and quickly dry out. Reweigh. What loss of weight in each case?

Conclusions. — 1. What causes this loss?

2. Compute the percentage of loss in each case. *Note.* — Most foods are more than one half water. About 65 per cent of the human body is water.

3. Can you think of any uses of water to animals and plants?

PROBLEM III

A study of the different groups of foods (nutrients)[1] *which living organisms need, and how to detect their presence.*

[1] The nutrients may be classified as, 1. Proteids (albuminous or nitrogenous foods). 2. Fats and oils. 3. Carbohydrates (sugars and starches). 4. Mineral matter. 5. Water. (Water is often classed with mineral foods.)

a. Starch

Materials. — Corn starch, iodine solution, and test tube.

Method. — Crush the starch, and add a third of a test tube of water to a bit as large as a pea. Add a few drops of iodine solution.[1]

Observation. — What change in color do you note? *Note.* — If a large amount of starch is present, the material will turn black; if a smaller amount, it will turn a deep blue.

b. Grape Sugar

Materials. — Glucose or grape sugar, [2] Fehling's solution or preferably [3] Benedict's second solution, test tubes, and alcohol lamp or Bunsen burner.

Method a. — Dissolve some glucose in water in a test tube. Add a few drops of Fehling's solution and boil.

Observation. — What change in color do you observe? *Note.* — If grape sugar is present in any substance, the contents of the tube will change to a yellowish, deep orange, or brick-red color.

[1] Iodine solution may be made by adding a few crystals of iodine to enough 95 per cent alcohol to dissolve it well. Or to 1 gram of iodine crystals, add $\frac{2}{3}$ gram of potassium iodide, and dilute to a dark brown color in 30 per cent alcohol.

[2] Fehling's solution may be made as follows: Add 35 g. of copper sulphate to 500 cc. of water. Solution No. 1.

To 160 g. caustic soda (sodium hydroxide), and 173 g. Rochelle salt, add 500 cc. of water. Solution No. 2.

For use mix equal parts of solutions 1 and 2. This may also be obtained of druggists, in tablet shape, — or address Jno. Wyeth and Bros., Philadelphia.

[3] Benedict's second solution. — Copper sulphate . . . . . 17.3 grams.
Sodium citrate . . . . . . 173.0 grams.
Sodium carbonate (anhydrous) 100.0 grams.

Make up to 1 liter with distilled water.

With the aid of heat dissolve the sodium salts in about 600 cc. of water. Pour through filter paper into a glass graduate and make up to 850 cc. with distilled water.

Dissolve the copper sulphate in about 100 cc. of water, and make up to 150 cc. with distilled water. Pour the carbonate citrate solution into a large beaker and add the copper sulphate solution slowly with constant stirring.

Method b. — Add 5 cc. of Benedict's second solution to about 8 drops of the solution under examination; such as the glucose solution. Boil the mixture for one or two minutes and let it cool slowly.

Observation. — What changes in color do you notice? *Note.* — If grape sugar is present the liquid will be filled with a *precipitate*, which may be red, yellow, or green in color, depending upon the amount of sugar present. The positive test is the *precipitate*, not the *color*.

c. Fats and Oils

Materials. — Nuts or animal fat, white paper, watch glass or other shallow vessel, and ether, chloroform, or benzene.

Method a. — Rub the nut or material to be tested on a piece of paper, and hold to the light.

Observation. — What effect do you notice when the nut is rubbed on paper? *Note.* — If oil is present, a translucent grease spot will appear.

Method b. — Put the substance to be tested on a piece of plain white paper and put it in a warm place, as on a radiator or in an oven.

What happens when nuts are so tested?

Method c. — Grind or crush the substance to be tested, as flaxseed; place it in a watch glass, add ether or benzene, and allow it to stand until it evaporates.

Observation. — Do you note anything sticking to the sides of the vessel? *Note.* — Ether, etc., dissolves and extracts oils from substances, and on evaporation leaves the oil on the container.

d. Proteids or Nitrogenous [1] Foods

Materials. — Raw and hard-boiled white of egg, feather or leather, nitric acid, ammonia, test tubes, spirit lamp.

Method a. — Place the substance to be tested in a test tube, and add a little strong nitric acid. Note any color that ap-

[1] Nitrogenous foods contain nitrogen, other foods do not. Good examples are peas, beans, white of egg, cheese, and lean meat.

pears. Rinse out the acid with water, and add a little ammonia, and again note any change in color.

Observations. — 1. What change in color when the acid is added? *Note.* — If a lemon-yellow color appears, it indicates the presence of proteid.

2. Is there a still further change in color when the ammonia is added? *Note.* — A deep orange color now appearing verifies the presence of proteid.

Method b. — Put some raw white of egg in a test tube, and heat it.

Observation. — What happens as the white of egg is heated? What change in color?

Note. — Any substance thickening and becoming white in color is said *to coagulate,* and indicates proteid in the form of an *albumin.*

Method c. — Burn a piece of leather, or meat, or feather.

Observation. — Note the peculiar odor of burning feather or leather. This shows the presence of a proteid.

e. Mineral Matters (Optional)

Method. — Burn a piece of meat in a spoon or shovel until no further change can be brought about by heat.

Observation. — What seems to be left in the spoon? Describe it.

f. Water (Optional)

Method. — Weigh the substance to be tested, as an ounce of meat. Put it aside in a warm dry place, until it is thoroughly dry, and then reweigh it.

Observations. — 1. What is the loss in weight of the meat?

2. What is the cause of most of the loss?

g. Summary

Conclusions. — 1. *a.* What do you conclude is a good test for the presence of proteids in a substance? *b.* Of fats and oils? *c.* Of starch? *d.* Of grape sugar? (*e.* Of mineral matter? *f.* Of water?)

2. Explain just what the test consists of in each case.

Home Work (Optional). — Apply the above tests to potato, eggs, bread, butter, and beans, and tabulate your results as follows: —

	POTATO	EGGS	BREAD	BUTTER	BEANS
Proteids					
Fats and Oils					
Starch					
Grape Sugar					
Minerals					
Water					

Put a check in the above tabulation wherever a nutrient occurs in any of the foods listed for testing. Does any one of the above foods contain all of the nutrients?

Questions

1. What is a food?
2. Name the nutrients in foods.
3. Give some examples of each of the nutrients.
4. Where do plants get their nutrients?
5. Where do animals get theirs?
6. How test for the different nutrients?

References

Hunter, *Essentials of Biology.* Chap. II. American Book Company.
Hunter, *Elements of Biology.* Chap. II. American Book Company.
Davison, *The Human Body and Health* (Advanced). Chap. V. American Book Company.

PROBLEM IV

An Introduction to the nature and work of living organisms.

Materials. — Specimens of any ordinary flowering plant, such as a buttercup or butter and eggs (*linaria*). Somewhat similar greenhouse plants may also be used, as a geranium or primula. Living insects, as locusts.

a. General Study of a Plant

Observations. — 1. Find four different parts to the plant. What are they?

2. What is the greatest difference between root and stem? Can you find joints in the roots?

3. Are the leaves arranged on the stem in a regular or irregular fashion?

4. Do you find any parts of the flower that appear like modified (changed) leaves?

5. How many circles of parts can be found in the flower? How many parts in a circle?

Conclusions. — 1. What do you think is one of the purposes (*functions*) of roots? Reasons?

2. What is one of the evident functions of the stem?

3. How are the leaves arranged so as to get the most sunlight?

4. Is there any relation between parts exposed to sunlight and the green coloring matter (*chlorophyll*)?

Note. — Roots, stems, and leaves are known as *vegetative organs*, as they are necessary to the life and growth of most individual plants.

5. What is produced by the flowers of apple trees? What is contained within the core of the apple? Then what do you think is the function of flowers? Why are they of especial importance?

b. General Study of an Animal

Apparatus. — Small glass jars covered with netting to serve as vivaria, or "live boxes," clover or grass, hand lens, bristles.

1. Activities

Method. — Place two or three live grasshoppers[1] in a vivarium containing some grass or clover, and observe them carefully for a few minutes.

[1] A live butterfly or any other living insect will do just as well.

Observations. — 1. Is it easy to see them in these surroundings? Explain.

2. Do they try to hide or conceal themselves?

3. How does a grasshopper walk? Which set of legs seems to be used the most in walking?

4. With a bristle cause a grasshopper to jump. Which pair of legs is used?

5. Can a grasshopper fly?

Conclusions. — 1. How are the jumping legs fitted (*adapted*) for their purpose?

2. How is the grasshopper adapted for flying?

3. What do you conclude is the most common mode of locomotion?

4. Why are the posterior or hind legs so differently placed as compared with the anterior or front ones?

2. Respiration

Observations. — 1. Note the movements of the abdomen. Are they regular?

2. Look for small breathing pores (*spiracles*) along the sides of the abdomen.

Conclusion. — Through what openings does a grasshopper breathe?

3. Feeding

Observations. — 1. Watch grasshoppers feeding in the vivarium. Do they hold the leaves lengthwise or crosswise of the mouth?

2. Note the upper and lower lips. Are they movable?

3. Find dark brown jaws, *mandibles*, underneath the lips.

Conclusions. — 1. Which way must the jaws move to meet the food?

2. What difficulty in eating would arise if there were no lips?

4. Sense Organs

Observations. — 1. Note the *antennæ* or "horns" of the grasshopper. What different positions do they take?

2. Can you find *compound eyes* (large)? Any others (small)?

Conclusions. — 1. Do the different positions of the antennæ seem to have any relation to the different movements or positions of the grasshopper?

2. From your study of a plant and an animal, what conclusions can you form concerning functions and organs?

c. A Study in Variation (Optional)

1. General Study

Observations. — 1. Compare the plant you are studying with another of the same sort. Are they the same height? Color?

2. How do the leaves differ in shape? Number?

3. How do the stems differ in size? Color? Veining? Hairiness? Shape of margins, etc., etc.?

4. How do the flowers differ?

Conclusions. — 1. Are plants of the same sort exactly alike?

2. Are any two persons exactly alike?

3. What do you conclude regarding differences between individual plants or animals?

2. Graphic Representation

Observations. — 1. Count the number of rays in a large quantity of any wild autumn flower, such as the ox-eye daisy or an aster. If such plants cannot be had, use any other wild plant and make the leaves or stems the basis of study.

2. Suppose the number of rays varies from six to thirty. Sort the plants into piles, putting all with six rays into the first pile, all with seven rays into the second pile, and so on. Which pile is the largest?

3. Let the small squares on the vertical lines of a sheet of cross section paper represent the number of flowers, or leaves, etc., in any particular pile, and number them with the number of rays noted. Choose every other line (to prevent crowding), and count up on the lines the number of squares that represent the number of flowers with the number of rays indicated, and make a small check. Thus in Figure 6, one flower was 6-rayed, 10 flowers were 14-rayed, 29 were 20-rayed, etc.

Now connect all the checks with a curved line, and we get what might be called the "curve of variation" for the particular kind of ox-eye daisy studied.

Note. — These variations are of the ordinary sort and may be called

fluctuating variations, to distinguish them from *sudden variations* or *sports*.

Conclusions. — 1. What sort of a rayed blossom does the above kind of plant tend to produce ? *Note.* — If the curve you get tends to be double, it would indicate a splitting up of the sort into two other sorts with rays predominating as indicated by the two longest lines, respectively.

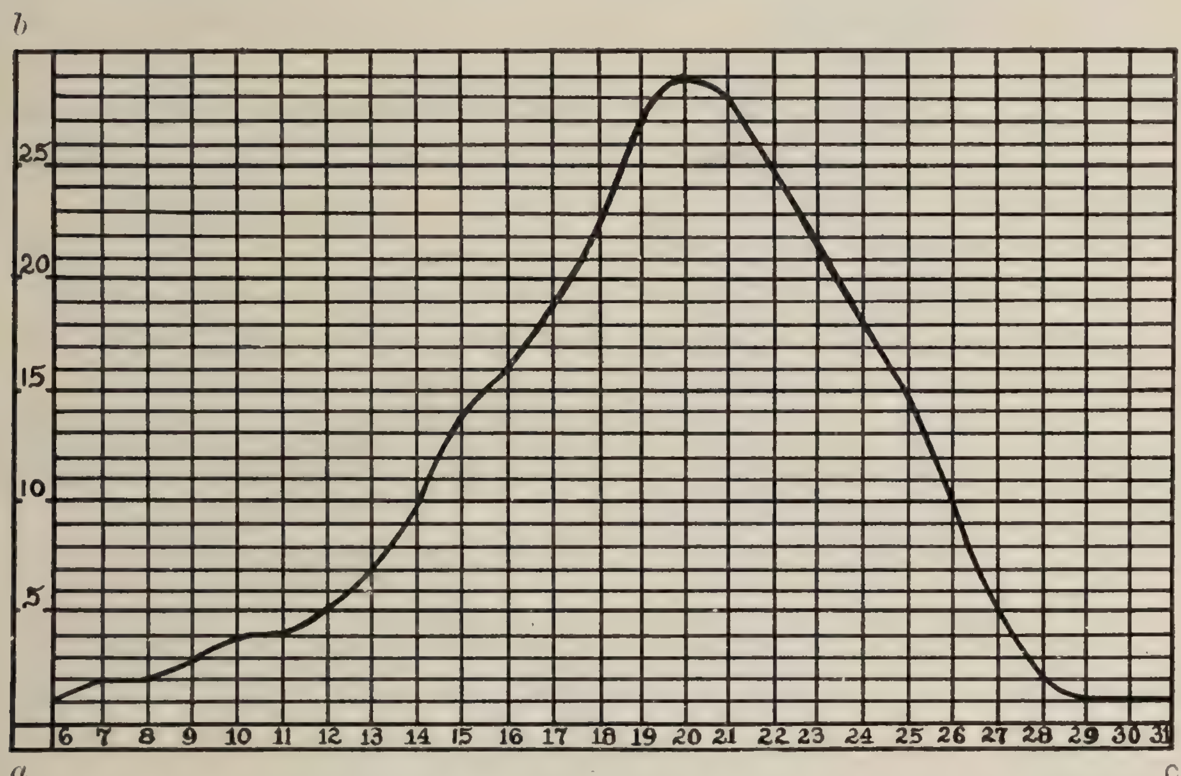

FIG. 6. — Curve of variation in number of petals of ox-eye daisy. Number of plants examined on line *ab*. Number of petals to a flower on line *ac*.

2. What tendencies of flower, or leaf, buds, stems, etc., are indicated by your figure ? *Note.* — Whoever wishes to improve plants must be on the alert to notice desirable variations and attempt to propagate them.

Questions

1. What are the four essential parts of a flowering plant ?
2. How are flowers of advantage to the plant that bears them ?
3. What do you think Tennyson meant by the following statement ?

> "but if I could understand
> What you are, root and all, and all in all,
> I should know what God and Man is."

4. What do you understand by the phrase "adaptation of structure to function" ?
5. What is meant by 'variation' in organisms ?
6. What use may man make of variation ?

References

Hunter, *Essentials of Biology.* Chap. III.
Hunter, *Elements of Biology.* Chap. III.
Bailey, *Plant Breeding.* Lecture I.
Osterhout, *Experiments with Plants.* Chap. X.

EXERCISE (Optional)

[1] *A study of the construction and use of the compound microscope.*

THE MICROSCOPE

1. *Note.* — The *microscope*, an instrument for making small objects appear larger, comprises two parts : the *stand* and the *lenses.*

2. *Note.* — The stand consists of the following parts : *foot* or *base*, *pillar*, *arm*, *tube*, *diaphragm*, *mirror*, *revolving nose piece*, the *coarse adjustment*, and the *fine adjustment.*

a. Describe the location of the perforation in the stage.

b. What is its use ?

c. What is the use of the revolving wheel, or *diaphragm*, pivoted to the stage ?

3. *Note.* — Below the stage is a movable bar carrying the *mirrors* or reflectors.

a. In how many different directions can you move the mirrors ?

b. What is the advantage of having them movable ?

c. What is the use of the mirrors ?

4. *Note.* — A hollow cylinder containing two lenses fits into the upper end of the tube. It is called the *eyepiece* or *ocular.*

a. Why is the name 'eyepiece' applied ?

5. *Note.* — Small brass cases, each containing several lenses, are attached to the tube at its lower end : they are the *object lenses* or *objectives.*

a. Why is the name 'objective' given to these lenses ?

b. How many objectives are there in your microscope ?

6. *Note.* — The *low power* (a slightly magnifying objective) has a short and broad case. The *high power* objective has a long and narrow case.

[1] Adapted from Hunter and Valentine, *Laboratory Manual.* Henry Holt and Company.

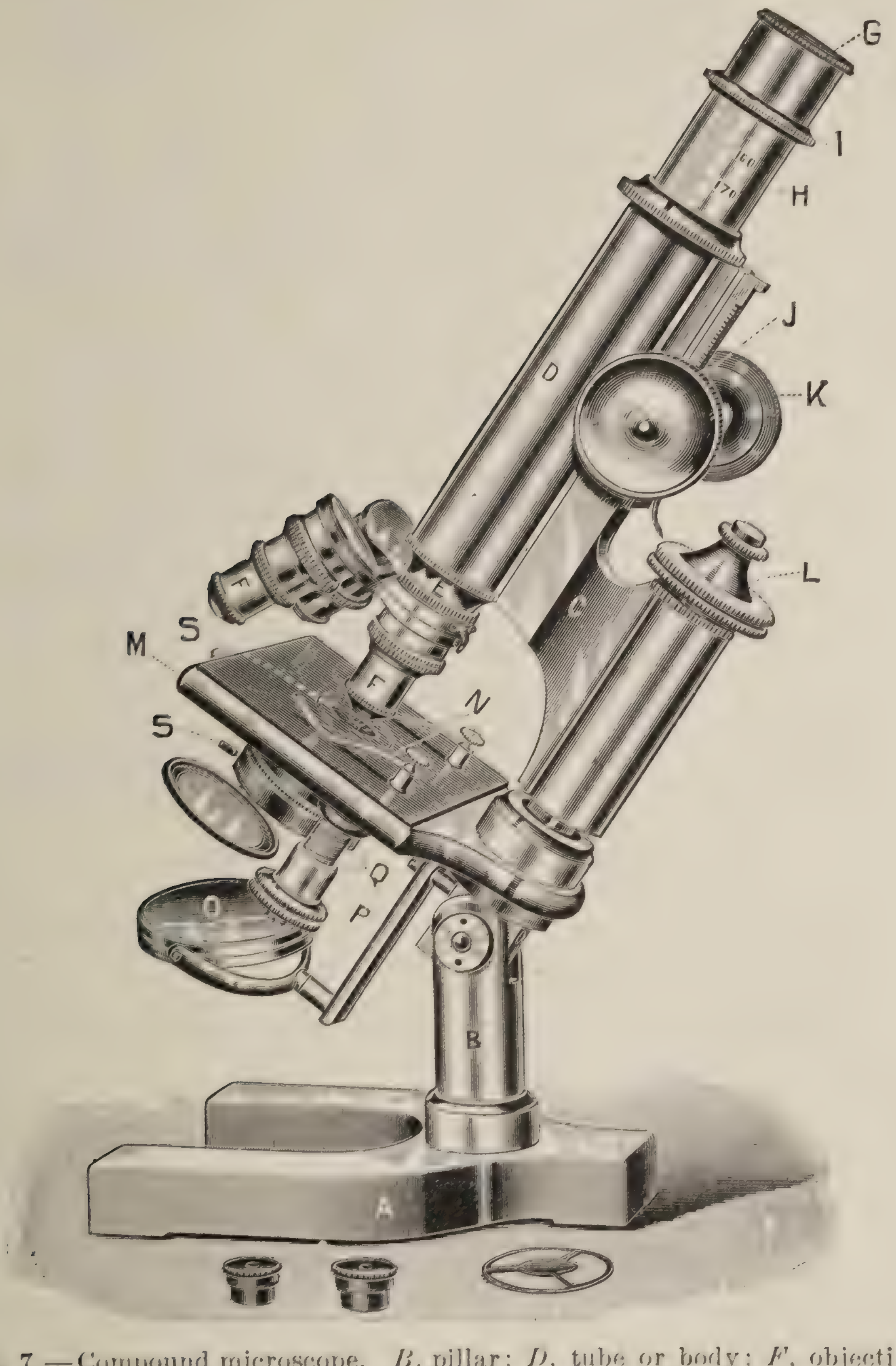

FIG. 7.—Compound microscope. *B*, pillar; *D*, tube or body; *F*, objective; *G*, eyepiece; *H*, draw tube; *J*, coarse adjustment; *K*, milled wheel; *L*, fine adjustment; *M*, stage; *O*, mirror; *S*, diaphragm.

a. What fractional numbers do you find on the case of the high and the low power objectives, respectively?

7. *Note.* — The objectives are attached to a revolving device, the *nose piece.*

a. What are the advantages of a revolving nose piece?

8. *Note.* — To obtain a clear image of the object under examination, we must be able to vary the distance between the lenses and the object; that is, to *focus* the instrument. The microscope is brought into focus by slightly turning either of the large wheels placed at the top of the arm near the tube.

a. Why are these wheels called the *coarse adjustment?* (Turn one of them gently.)

b. What movement results?

9. *Note.* — The milled head of the *fine adjustment* is found at the top of the pillar.

a. Carefully turn the fine adjustment back and forth. (*No more than half a turn in either direction.*) Why is this adjustment called 'fine'?

CAUTIONS AND HINTS

1. Do not touch either lenses or mirrors.
2. Do not rest either your arm or your head on the instrument.
3. Never make more than half a turn either way with the fine adjustment.
4. Get a fairly clear image with the coarse adjustment: use the fine adjustment only to complete the operation of focusing.
5. An object to be viewed with the compound microscope should be very thin and transparent.

PRELIMINARY PRACTICE WITH THE MICROSCOPE

Materials. — Slides, cover glasses, free-hand sections of potato tuber stained with iodine solution, compound microscope.

Directions for Mounting Sections and Adjusting Microscopes. —

1. Place the given section on a slide in a drop of water.
2. Clean a cover glass and lower it gently over the object. (Avoid air bubbles!)
3. Put the slide on the stage with the object over the stage perforation.
4. Tilt the mirror so that the object may be well lighted.
5. By aid of the coarse adjustment, bring the low power near to the object.
6. With your eye at the ocular, raise the tube from the stage till the image appears rather clearly.

7. Make the image entirely clear by a slight turn of the fine adjustment to one side or the other.

a. Study of Cells and Starch Grains

Direction. — Study the *cellulose* walls inclosing spaces in which lie the deeply stained starch grains.

1. What color does cellulose show under the microscope?
2. What color is shown by starch grains treated with iodine?

b. Study of a Drop of Milk (an Emulsion)

1. Place drop of milk on slide. Cover with slip. Notice the small globules of fat floating in a liquid. Are all these of the same size?

2. Are they equally abundant in all parts of the field?

Note. — A liquid containing large numbers of tiny fat droplets is called an *emulsion*.

3. Shake some olive oil and water together in a test tube. What is the color? Appearance?

PROBLEM V

The structure and general properties of living matter.

a. General Structure

1. Single Cells

Method. — Scrape off some of the green "dust" so commonly seen on the north sides of trees and allow it to stand in water for a day or two. Mount some in a little water and study with the compound microscope,[1] first using low power, then high power. ([2] Dem.) Optionally use any one-celled alga, as *desmids*.

Observations. — 1. What is the color of a single plant (cell)? Form?

2. Are the cells alike? If not, what differences?

3. Do you find any cells splitting into two or four parts?

[1] Much may be accomplished by setting one microscope so that pupils may see the demonstration in turn while the rest are studying charts, references, etc., or making sketches, at the discretion of the teacher.

[2] Dem. indicates a demonstration by the instructor. Here introduce a short study of the use of the microscope. See Exercise, page 32.

4. *Note.* — The outer covering of a cell is known as a *cell wall*, its contents is the living matter of the cell, or *protoplasm.* The green coloring matter is *chlorophyll.* The protoplasm is further separated into a small darker lens-shaped body, the *nucleus*, and a surrounding portion, the *cytoplasm.*

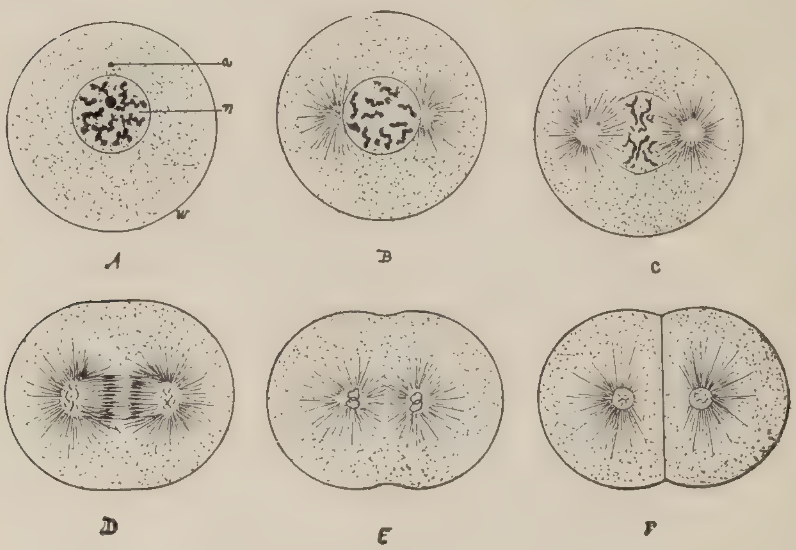

FIG. 8.—Parts of a cell, and stages in the division of a cell to form two cells.

Try finding cell wall, nucleus, and chlorophyll in your specimen. Also in Figure 8.

5. *Dem.* — Show any single-celled animal of a hay infusion. What are the most evident differences between these cells and the plant cells?

Conclusions. — 1. Are the individual plants one-celled or many-celled?

2. How does this plant form new plants or reproduce?

3. How distinguish plant cells from animal cells?

Note. — Some special cases are difficult to decide, but do not concern us now.

4. What is a cell?

2. TISSUES AND ORGANS

Method. — Scrape some cells from the inside lining of the cheek with a sterilized knife. Mount in water. Stain with methyl green. The outer skin of a frog and onion skin may also be used in the same manner.

Observations. — 1. Look for cell walls, nuclei, etc.

2. What is the shape of a single cell?

3. Are the cells evidently free, or mostly united with one another?

Note. — Where cells are united, whether in plant or animal structure, they are said to form *tissues*. Thus there is nerve tissue, muscle tissue, etc., in animals, and there are many other tissues in plants.

FIG. 9. — Drawings of sections of cells. Showing some various sorts much magnified. *b*, bone cell; *c*, epithelium cell from the intestine; *e*, flat epithelium cell from the mouth; *f*, fat cell; *n*, nerve cell from the brain; *m*, muscle cell.

4. **(Optional.)** — Sketch a few of the cells stained with methyl green, especially showing cell walls, nuclei, and relations to one another.

Conclusions. — 1. Distinguish between one-celled and many-celled plants or animals.

2. In what ways are plant and animal cells alike? How unlike?

3. What are tissues? What is the unit of their structure?

Note. — Tissues are grouped in both plants and animals to form *organs*, — as a leaf, a root, the hand, the eye, etc.

b. Simple Properties

Note to Teacher. — Spirogyra, or pond scum, stamen hairs of spiderwort (*tradescantia*), leaves of nitella, vallisneria, elodea, or the root hairs of almost any aquatic plant are good for this exercise. Unless time is no object, it is likely better simply to set up a few microscopes with any of the above

preparations under high power, and permit the pupils, one at a time, to briefly note the protoplasmic movements.

Since elodea is quite common in ponds and streams, and is so easily kept on hand in aquaria, it is recommended as best for the present purposes.

Observations. — 1. Examine a bit of mounted living leaf of elodea or other selected study. What is the general color? Can you see cell walls?

2. Are the cells single, or joined in a tissue?

3. Look closely for any indications of movements in the cell — moving protoplasm. What is its appearance?

4. Does the protoplasm (cytoplasm) move in any special ways with reference to the nucleus?

Conclusions. — 1. In what part of plants may protoplasm be found?

2. Write a paragraph, telling of the appearance, movements, etc., of protoplasm.

Questions

1. What is a cell? Tissue? Organ?
2. What is an organism? Give reasons for your answer.
3. What is protoplasm? Cytoplasm? Nucleus?
4. What is the unit of structure of living things?
5. What are some of the properties of living things?
6. How may cells reproduce?
7. What do you suppose is meant by the statement "one touch of nature makes the whole world kin"?
8. Why is it necessary that there should be differences of function among the cells of a body?
9. Why could not a cell in the body provide for its own wants?
10. What happens to a body if part of the cells fail in their work?
11. Mention some points in which the body reminds you of a community of people.
12. What are some of the needs of a cell?

Special Reports

1. The cell theory of Schleiden and Schwann. (See *Foot-Notes to Evolution.*)
2. Protoplasm and its properties.
3. The human body or a plant as a colony of cells.

References

Hunter, *Essentials of Biology.* Chap. III.
Hunter, *Elements of Biology.* Chap. III.
Jordan, *Foot-Notes to Evolution*, pp. 147–148.
Thompson, *Animal Life.* Chap. XI.
Davison, *The Human Body and Health* (Advanced). Chap. II.
Ritchie, *Human Physiology.* Chap. I.

To express a thought in one's own language is worth ten times more for mind growth than to state it in words learned from the book. — DAVISON.

PHYSIOLOGICAL PROCESSES AND RELATIONS IN PLANTS

PROBLEM VI

The structure and work of the parts of a simple flower.

Materials. — Any simple flower, such as the buttercup, sedum, etc., hand lens, compound microscope, sugar solution.

a. The Flower

Observations. — 1. Find green leaflike parts (*sepals*). How many are there?

2. Are they separate or united? *Note.* — The sepals taken together constitute the *calyx.*

Conclusion. — What do you conclude is their *use* or *function?*

Observation. — How many colored parts (*petals*) are there?

Note. — The petals taken together form the *corolla.*

Conclusion. — Can you think of any functions of the corolla?

Observations. — 1. Observe a number of slender stalks (*filaments*), with dusty knobbed ends (*anthers*), which taken together are called *stamens.* How many stamens are there?

2. Find just how the anthers are joined to the filament.

3. What is the color of the anthers? Appearance?

4. Can you find dustlike material (*pollen*) on and in the anthers?

5. Can you find places in the anthers through which the pollen has escaped?

6. Find some podlike structures (*pistils* or *carpels*), located in the center of the blossom. How many are there?

7. Note the broad base (*ovary*) of a pistil. Also find a more or less stalklike portion (*style*) which terminates in a roughened sticky tip (*stigma*). *Note.* — The stigma usually has upon it a sweet, sticky substance in which pollen grains may grow much as a seed would sprout.

Conclusion. — Do the stamens and pistils have the same or different functions? Reasons for your answer?

Drawings. — 1. A flower from above. Label all parts.

2. A stamen, showing all parts.

3. A pistil, showing all parts.

Observations (*Home Work*). — 1. Locate some flower buds. Carefully remove the calyx from one of them. After a time compare in development with other buds. Result?

2. Remove the corolla from another bud. Do insects visit it?

3. Remove the stigma from another young blossom. Effect on fruit after a few weeks?

4. Cover a cluster of flower buds with a paper bag. Effect on fruit in a few weeks?

Conclusion. — Name a function of the calyx; corolla; stigma; pollen (as decided by experiment).

b. Pollen

Method. — Dust some buttercup pollen on a piece of paper, or a glass slide. Examine it with a hand lens. Make a solution of about 20 grams of sugar with about 80 grams of water. Make another solution about one half as strong. Place some of each solution in watch glasses, and dust some ripe pollen in each. Place them under a small bell jar with a moist sponge, and examine them from time to time with the low power of a compound microscope. Also try tulip or narcissus pollen in 3% cane sugar solution, sweet pea or nasturtium pollen in 15% cane sugar solution.

Note. — Some prefer to make a "hanging drop" preparation by placing a drop of the solution used with some pollen on a cover glass and inverting it on a small ring which has been placed on an ordinary slide. Seal it with vaseline, and watch for sprouting pollen.

Observation. — Find any sproutlike tubes (*pollen tubes*) extending from the pollen grains. Describe them, or sketch a few.

Conclusions. — 1. Are the stigmas in a blossom in such a position that pollen might commonly reach them? Explain.

2. The sugar solution served as food for the growth of the pollen tube. Can you see any reason for there being a similar solution on the stigma?

Note. — The pollen tube is long and threadlike, and carries in its growing end a very important structure (*sperm cell*). (See Figures and Charts for further explanation.)

c. The Pistil

Materials. — Pistils of such flowers as lily or tulip, some cut lengthwise and some cut crosswise. Chart or text Figures.

Observations. — 1. Find a number of rounded bodies (*ovules*) in the ovary. Describe one.

2. Are the ovules few or abundant?

Note. — The ovules become seeds if the sperm cell in the tip of the pollen sprout ever succeeds in reaching a somewhat similar cell (*egg*) located in the ovule. The pollen grain sprouts in the sweet food on the stigma, and sends the sprout down through the style until finally the two cells — the sperm cell and the egg cell — unite to form a single cell. See Figure 85. The egg is now said to be *fertilized*, and the process is known as *fertilization*. The fertilized egg now develops a minute structure called the *embryo*, and the ovule is now a *seed*. The embryo of the seed will develop into the future plant when the conditions needed are present.

We now see that only pollen and eggs are necessary for the formation of seeds, — so the *anthers* and *pistils* are known as the *necessary* or *essential organs*.

PROBLEM VII

A study of cross-pollination and some of the means of bringing it about.

a. Adaptations in the Flower

Method. — Study the structure of a butter and eggs or similar blossom, looking for any adaptations or fitness for cross-pollination or fertilization.

Observations. — 1. Are the sepals of the same size and shape, *i.e.* regular?

2. How do the petals and sepals compare in number? In size and shape? Might the pollen that finally reaches the stigma more likely come from the same flower (*Self-fertilization*) or from a different flower (*Cross-fertilization* or *pollination*)?

3. See if you can make out the landing place of a bee should it visit this flower for nectar or honey.

4. Find the anthers and stigma. Can the pollen readily reach the stigma without some outside aid?

Conclusion. — Show how such a peculiar form of corolla fits it more especially for the visits of bees.

b. Adaptations in an Insect Agent

Method. — Study dried or alcoholic specimens of the bumblebee or honeybee.

Note to the Teacher. — In place of using the following questions it may be well to try permitting the pupils to ask and answer their own questions. In fact, this should be done wherever it seems feasible.

Observations. — 1. How many distinct regions has the body?

Note. — These regions are known as the *head, thorax,* and *abdomen,* in order.

2. How many pairs of wings do you find? Of legs? To what part of the body are they fastened?

3. Do you find mouth parts fitted for biting (jaws), or for sucking, or both?

4. Are the legs *segmented* (jointed)? What structures do you find on the feet?

5. Are the legs smooth or hairy? If hairy, which segment is the most so?

Conclusions. — 1. What do you think is the purpose of joints in the legs? What would be the result if there were no joints?

2. What do you think is the purpose of hooks on the feet?

3. Could the hairy legs hold pollen? Which segment could carry the most, if any?

4. How do you think an insect may be an aid in cross-fertilizing flowers?

5. How does a flower serve the bee? How, in turn, does the bee serve the flower?

c. Field Work (Optional)[1]

1. General Work

Observations. — 1. Visit a locality where flowers are abundant. Are they being visited by insects?

2. Can you tell what sort of insects? Are they few or abundant?

3. Do bees visit flowers of *one sort* in succession, or of different sorts?

4. If butterflies are present, try to determine as for the bees.

5. Describe any peculiarities of the flowers visited by the bees, such as irregularity, strong perfume, nectar, etc.

Conclusions. — 1. Write out a report of your observations in a notebook. Bring it to class conference for discussion.

2. What is evidently the purpose of irregular flowers? Of nectar? Of perfume?

[1] It would also be interesting to see if any flowers prevent pollinating their own pistils, or if there are any devices for preventing the visits of unsuitable insects.

2. Special Directions for the Study of some Fall Flowers.[1]

Field Flowers. — Let us now take up some common wild flowers easily found in the fall of the year, and work out the relation of the parts of the flower to its insect visitors. Remember that the important part of these exercises is to find how and by what means the flower is adapted or fitted to receive the visits of insects. This work can be done best on field trips, but it can readily be modified so as to be useful as a schoolroom exercise.

The Evening Primrose (*Onagra biennis*). — The habitat preferred by this flower is dry fields, roadsides, or waste places. The yellow flowers are found in long, upright, densely crowded clusters. A flower cluster in which the individual flowers have no flower stalks or pedicles, with one main axis to the cluster, is called a *spike*. Notice that young and old flowers and fruits are all on the same cluster. Where are the youngest flowers located in the cluster? Is there any flower at the end of the main stalk? Could you determine in advance the length of the flower cluster? Such a cluster is said to be *indeterminate*. Why? Study a single open flower. Note the calyx and corolla; are the parts distinct? How many petals do you find? Notice that there are eight stamens and that the stigma is four-parted. Cut the ovary in cross section, and see how many locules (spaces) there are.

When a flower has each circle of parts, as the sepals, petals, stamens, and pistils, made up of a certain number of divisions, or when they appear in multiples of that number, the flower is said to be *symmetrical*. Here we see a very striking example of symmetry in a flower.

The chief attraction to insects is the *nectar*, which is formed in nectar glands at the base inside the slender tubular corolla. Information is given to the insects of the contents by a faint, sweet odor. This flower is not visited by many day-flying insects. Can you determine the names of any that do come by day? At night the flower opens more widely and the scent becomes much more noticeable. Moths are its chief night visitors. The long proboscis is thrust into the flower and quickly withdrawn, but usually a little pollen is carried off on the *palps* (projections on the sides of the head). This may be left on the next flower visited.

Try to determine what other insects, if any, visit the evening primrose at night.

Draw a single flower split open lengthwise to show the position of the parts, and especially any adaptations to insect pollination. Look for any special means for the prevention of self-pollination. Label all the parts.

Moth Mullein (*Verbascum blattaria*). — The moth mullein is one of the most beautiful weeds, despite the fact that few blossoms are found at any given time. The plant flourishes on dry, waste land, roadsides, and open fields. It was introduced into this country and has since become common here and in Canada.

The flowers are found in a long, loose *raceme*. A raceme is like a spike, except that each flower has its own flower stalk developed. Has

[1] Adapted from Hunter, *Elements of Biology*.

this cluster yellow or white flowers? Into how many parts is the calyx divided? The corolla? Is the corolla perfectly regular? Notice the five stamens; is there anything peculiar about the filaments? Are they all of the same length? In spite of the fact that the flower is called moth mullein, it is not pollinated to any extent by moths. Bees and flies are the chief pollen bearers. Bees which alight on this flower do so for the purpose of collecting pollen. This they usually gather from the short stamens while they cling to the longer ones. As the bee lights on another flower, the pollen on the under side of the body is transferred to the stigma of this flower.

Draw the flower from above, twice natural size.

Jewel Weed (*Impatiens biflora*). — One of the most prevalent of all our brookside flowers is the jewel weed. It well deserves its name, a pendent flaming jewel of orange.

The flower is very irregular in shape. Are the flowers single or in clusters? The sepals as well as the petals are colored. The former are three in number, one of which is saclike in shape and contracted at one end into a spur. The petals are also three in number. Open the flower. Notice how short the filaments of the five stamens are. Make a note of their position with relation to the pistil. Would self-pollination be possible in this flower?

If it is possible to study jewel weed out of doors in its native habitat, it will be found that humming birds are the visitors which seem best adapted to cross-pollinate the flower. A careful series of observations by some girl or boy upon the cross-pollination of this flower might add much to our knowledge regarding it.

Jewel weed has the habit of producing (usually in the fall) inconspicuous flowers which never open but which produce seeds capable of germination and growth. Such flowers are said to be *cleistogamous*. In England, where the plant has been introduced, it is found to produce more cleistogamous flowers than showy ones, and the showy ones do not produce seed. There are no humming birds in England, and without this means of pollination, the cleistogamous form prevails. Make a front view drawing of the flower of jewel weed twice natural size.

d. Other Agents

Method. — Refer to or study as many other flowers as possible. Study the Figures of other types, using charts or texts.

Observations. — 1. Seek for any peculiarities of structure that would lead you to think that they are for purposes of pollination. If possible, especially study the structure of the sage blossom, pea or bean, and violet.

2. Find out how pollination is accomplished in the corn plant and the willow.

3. Find out the same thing for pines. Eel grass. Primrose. Jack in the pulpit. Iris. Orchids.

Conclusion. — In what other ways do you find pollination may be brought about? Tabulate your results as follows: —

Agents of Pollination	Examples
Insects	
Wind	
Water	
Other agents	

Questions

1. How is a sage blossom fitted for the visits of insects?
2. Do all flowers of an apple tree produce seeds? How do you know?
3. Why do flowers produce an abundance of pollen?
4. Why does a "volunteer" stalk of corn standing alone in a garden commonly have but a few grains of corn on the ear?
5. Do insects intentionally carry pollen?
6. Why do bees visit flowers?
7. Does the odor of flowers seem of any consequence? Nectar?
8. What is the importance of color in flowers?
9. Have you ever seen insects moving from flower to flower? What do you infer?
10. Show why bees are likely to visit flowers before the pollen is ripe, or the stigma ready to receive it.
11. Do you infer that bees are able to see, smell, and taste?
12. What other insects have you ever seen visit flowers?
13. Could a solitary willow bear seeds?
14. What determines the position of the flower and fruit?
15. What animals other than insects act as fertilizing agents?
16. Night-opening flowers are commonly white, sweet-smelling, and large. Is this of any advantage?

17. Do any flowers have arrangements for protection against undesirable visitors?

18. What are the essential organs of a flower? Why so called?

19. What is artificial pollination? What is its importance to man?

20. What do you think Bryant meant when he wrote: —

> To him who in the love of Nature holds
> Communion with her visible forms, she speaks
> A various language; —

21. Do flowers cross-fertilized by the wind have gayly colored corollas? Odor? Nectar? Explain.

References

Hunter, *Essentials of Biology.* Chap. IV.
Osterhout, *Experiments with Plants.* Chap. VI.
Müller, *Fertilization of Flowers.*
Weed, *Ten New England Blossoms.*
Gibson, *Sharp Eyes* and *My Studio Neighbors.*
Darwin, *Cross- and Self-fertilization*, etc.
Ely, "Color Arrangement of Flowers." *Scribner's Magazine*, March, 1910.
Dana, *Plants and their Children.*
Dana, *How to Know the Wild Flowers.*
Stack, *Wild Flowers Every Child Should Know.*
Gibson, W. H., "The Milkweed," in *My Studio Neighbors.* p. 227.

PROBLEM VIII[1]

A study of fruits.

Note. — A fruit is here defined as a ripe or ripening ovary or seed case, with its contents and any attached parts.

Materials. — Pea pods or bean pods, apples, etc.

[1] The seed experiments for Problems X–XIV should be started now.

a. Uses to the Plant

1. Peas or Beans. (Legumes.)

Observations. — 1. Examine an unopened pod. Can you find the ovary or seed case? Style and stigma?

2. Open a pod and see if you can verify the above.

3. Note that the ovules are not all the same size.

Conclusions. — 1. Can you explain why the ovules are not all the same size?

2. Can you think of at least one function (use) of a fruit?

3. Sketch a half pod, with the contained ovules. Label all parts.

2. Apple. (A pome.) (Optional.)

Materials. — Preserved or fresh apple blossoms in various stages. Apples.

Observations. — 1. Find the calyx in an apple blossom. Are the sepals separated at the base or united? Thin or thick?

2. What part of the blossom seems most likely to develop into the fruit?

3. Do you find any indications of the calyx remaining on an apple?

Conclusions. — From what does the fleshy part of an apple develop? Give some reasons for your answer.

Observations. — 1. Remove the skin from an apple and leave the pared apple exposed to the air for a few hours. What results? (Weigh the apple both before and after the experiment.)

2. Break the skin of an apple and set the apple aside for a few days. Note what results.

Conclusions. — 1. What are some of the functions of the skin of fruits?

2. Cut cross and longitudinal sections of an apple. Can you find the seed cases (locules) of the ovary? How many are there? What seems to be their function?

b. Means of Scattering Fruits and Seeds

Materials. — Fruits of linden, burdock, oxalis, clotbur, thistle, beggar's tick, violet, maple, tumbleweed, dandelion, coconut, crane's bill, cherry, raspberry, acorn, nuts, peach, chestnut, pines, pea, peanut, jimson weed, green berries, etc.

Observation. — Study as many of the above fruits as may be available, and classify under the following table, giving means of dispersal.

Explosive	Wind-carried	Burs, etc., on Furry Coats, etc.	Squirrels	Birds	Man	Other means

Conclusion. — 1. Write a paragraph on the different ways seeds may be dispersed, and give an example of each.

c. Protection from Animals (Optional)

Observation. — Examine as many specimens of the fruits provided as possible, and see if you can tell just how they protect themselves from being destroyed by animals. Tabulate your results under the following headings: —

Bitter or Sour Taste while Young	Hard Covering	Spines	Suspension on Slender Stalks	Concealed Under Ground	Other Means

Conclusion. — How may fruits protect themselves from animals? Give examples.

d. Field Work

Observations. — 1. Visit a vacant lot, a city park, or country fields, and collect as many examples of fruits scattering their seeds as you can. Get the common names of those you do not know from your instructor. Label some boxes, using the headings of the two preceding exercises, and sort the material in the proper boxes. Give them to the school museum, if you so desire.

2. Take as many notes as you can concerning any observations you may make in the field. Note especially the means of protection and distribution, even though you may not know the name of the fruit until told.

Questions

1. Why do most plants produce a large number of seeds?
2. What advantage to plants that their seeds be widely distributed?
3. Are cotton fibers on the fruit or on the seed?
4. Visit some vacant lot and observe how the common weed seeds there are scattered.
5. What is the purpose of fleshy fruits?
6. Is an ear of corn a fruit, or a collection of fruits?
7. What is the purpose of the husk of corn?
8. What is the purpose of the bright colors and sweet tastes of fruits?
9. How might coral islands far at sea become supplied with various seeds?
10. How might the seeds of undesirable plants be brought to this country?
11. How might railroads affect seed dispersal?
12. Should a weedy vacant lot be burned over in the fall or in the spring? Explain.
13. Describe the process by which plants produce fruits.
14. What is the chief use of fruits to plants?

Special Reports

1. The work of Luther Burbank.
2. The spread of the Russian thistle.
3. The spread of the wild lettuce.
4. Weeds that have been imported, and how they were brought here.
5. The struggle of plants for existence.
6. The economic value of fruits.
7. The part taken by Indian corn in the development of America.
8. The wheat crop as an index to a country's prosperity.
9. The various uses of fruits.
10. Boards of Trade and their work.
11. Cotton and its part in the development of the United States.

References

Hunter, *Essentials of Biology.* Chap. V.

Osterhout, *Experiments with Plants.* Chap. VII.

Hodge, *Nature Study and Life.*

Rusby, "Wild Foods of November." *Country Life in America*, November, 1906.

—— "Wild Foods of the U. S. for September." *Country Life in America*, October, 1906.

Dickson, Harris, "Dethroning King Cotton." *Saturday Evening Post*, July 2, 1910.

Beal, *Seed Dispersal.*

Walton, *Practical Guide to the Wild Flowers and Fruits.*

Boynton, "Seeds Stealing a Ride." *Nature Study Leaflet, No. 4*, October, 1909. Cornell Univ.

"Seed Dispersal," *Home Nature Study Course*, Cornell Univ., No. 1, October, 1904.

Thompson, "Emergency Foods in the Northern Forest." *Country Life in America*, September, 1904, p. 438.

PROBLEM IX

The economic value of some fruits.[1]

Method. — Collect as many different kinds of fruits as possible, orchard fruits, garden fruits, etc., as berries, beans, pumpkin,

[1] The pupils should be encouraged to bring pertinent newspaper or magazine articles to class. These may be pasted in a proper notebook and indexed. It is also wise to catalogue all the better articles.

tomato, cucumber, etc., also nuts, grapes, market fruits, weed fruits, etc. Sort them into two groups — the fleshy fruits and the dry fruits. Pick out and label a sample of each sort for the school museum. Fill out the following tabulation as far as you can. (See References.)

1. Useful

Fruits	Native Home or Habitat	Annual Cash Value	Uses to Man
Garden Fruits:			
1. Peas			
2. Beans			
3. Pumpkins			
4. Cucumbers			
Etc.			
. . . .			
. . . .			
Orchard Fruits:			
1. Apples			
2. Pears			
3. Peaches			
4. Quinces			
5. Apricots			
6. Plums			
7. Cherries			
Etc.			
. . . .			
. . . .			
Grains:			
1. Wheat			
2. Rye			
3. Corn			
4. Oats			
5. Barley			
6. Rice			
Etc.			
. . . .			
. . . .			

Fruits	Native Home or Habitat	Annual Cash Value	Uses to Man
Miscellaneous:			
1. Cotton			
2. Bananas			
3. Coconut husk			
4. Coffee			
5. Cocoa			
6. Pepper			
7. Opium			
Etc.			
. . . .			
. . . .			

2. Harmful

Fruits	Native Home or Habitat	Estimated Loss	How they do Harm
Weeds:			
1. Wild lettuce			
2. Purslane			
3. Pigweed			
4. Ragweed			
5. Canada thistle			
6. Cocklebur			
7. Wild carrot			
8. Oxeye daisy			
9. Dandelion			
10. Milkweed, etc.			

Questions. — 1. What kinds of fruits can you buy in the market to-day? What prices do they bring?

2. How many kinds of corn do you know?

3. What part did Indian corn play in the discovery of America?

4. What is the most important index of a country's prosperity?

5. Name the two best corn producing states. Wheat. Rice.

6. Name some of the uses of Indian corn.

7. What part have the cereals played in civilization?

8. Explain the statement made by J. Ogden Armour, "The call of the farm must be made the answering cry to the wail of the hungering city."

References

Hunter, *Essentials of Biology*. Chap. IV.
Hunter, *Elements of Biology*. Chap. V.
Gannett, Garrison, and Houston, *Commercial Geography*. Chap. IX.
Huntington, A. O., "Poisonous Vagrant Weeds," *House and Garden*, September, 1909.

PROBLEM X

A study of seeds in their relation to the new plant.

Materials. — Kidney or lima beans soaked in water for 24 hours, dry pods of beans, vaseline, iodine solution, nitric acid, ammonia, and demonstration microscope.

INTRODUCTION

Bean Pod and Bean

Observations.— 1. Find the ovary, style, and stigma. How distinguish them?

2. Open the pods, and find the seeds. Where are they fastened? Note that each seed is fastened by a little stalk (*funiculus*).

3. Pull a bean from its attachment. Find a scar (*hilum*), showing where the funiculus was attached. Where is it located?

4. Look for a tiny hole (*micropyle*), near the hilum.

Conclusions. — 1. What is one of the functions of a fruit?

2. Can you think of any function of the micropyle? Keep in mind that it leads to the egg cell.

a. Relation of Embryo to Food Supply

1. Internal Structure

Observations. — 1. Remove the outer coat (*testa*) of a soaked bean. Look for another coat under it.

2. Into how many parts (*cotyledons*) does the rest of the bean naturally separate?

3. Remove one cotyledon (seed leaf) very carefully, and find some minute leaves (*plumule*). Where are they situated?

4. Find a rodlike part (*hypocotyl*).

Note. — The plumule later develops into the first true leaves of the plant, while the hypocotyl develops into the root and lower stem. The embryo includes all the parts of the seed that will later develop into parts of the young plant. Name these parts.

Conclusions. — 1. What do you think is the use of the seed coats?

2. What structures suggest the stem of the developed plant? Root? Leaves?

3. How has the embryo been fed and protected up to this stage?

2. Food Supply of the Embryo

Note. — For food tests see Prob. III, or, see Hunter, *Essentials of Biology*, Chap. V.

Observations. — 1. Crush a bit of soaked bean cotyledon, and add a few drops of iodine solution. What results?

2. Put some of this material on a glass slide and view through the demonstration microscope. Find small oval bodies stained bluish or black with the iodine.

Conclusions. — 1. What food material is in the cotyledon? Proof?

2. What are the oval bodies seen through the microscope?

Observations. — 1. Add nitric acid to some crushed cotyledon. What color appears? Rinse off the acid, and add ammonia. What color?

2. Put some crushed cotyledon on a piece of paper, put it in a hot place and leave it for several hours. What results?

Conclusions. — 1. What other food materials do you think are present? Reasons?

2. What foods then form most of the first food of the young bean plant?

3. Where is most of the nourishment for the growing bean embryo stored?

3. Another use of the Micropyle (Optional)

Method a. Observations. — 1. Cover the micropyles of a few beans with vaseline. Select as many more not covered with vaseline and weigh both lots. Leave both lots in water over night. Reweigh. What difference in weight do you find? What difference in appearance, if any?

Conclusions. — 1. What is one of the uses of the micropyle?

2. What other use of the micropyle do you already know?

Fig. 10. — Seeds half submerged in wet sand or sawdust, to determine how the water enters. (After Osterhout.)

Method b. Observations. — 1. Fill a cigar box with wet sand or sawdust. Place on the surface some corn grains or beans in rows, one third with the micropyle up, one third with the opening down, and one third flat on the soil as in Figure 10. Press them firmly into the soil so that each is just half buried. Which sprout first?

Conclusions. — 1. Where may the water enter seeds?

2. Does the seed's natural position in the soil usually bring the opening in contact with the earth? Explain.

b. How the Young Plant Makes Use of the Food Supply

1. Digestion

Observations. — 1. Cut lengthwise through the embryo of a number of corn grains that have just begun to germinate. Place them in a test tube and test for grape sugar. (Look for

slight changes in color about the margins of the embryo.) Result?

2. Chew some cracker slowly. Is there any change of taste?

Note. — When starch is changed to grape sugar by a substance found in plants or animals, the starch is said to be *digested.* In plants this may be accomplished by a digestive ferment, or *enzyme,* called *diastase*; in the mouth, by a ferment in saliva (*ptyalin*).

Method. — Add about 1 gram of diastase powder (commercial) to the same amount of starch and dilute with about 100 times as much water. Set aside in such a place that it will remain at about blood heat. Test for starch at the end of 24 hours. Result? Likewise test for grape sugar. Result?

Note. — A substance is soluble if, when it is put in water, it *entirely* disappears from view, just as sugar or salt when placed in hot water.

Conclusions. — 1. How do you conclude insoluble starch of plants may be changed into a form which is soluble?

2. Of what benefit is it to a plant that its food matter be stored in an insoluble form?

3. Which sort of food material might more readily circulate about in a plant, starch, or sugar? Explain.

4. Why is it necessary, then, that plants as well as animals digest starchy and other foods?

5. What evidently happens when you chew a cracker slowly in the mouth?

Questions

1. Why are beans of value as food for man?

2. What other seeds can you name that are used as food for man?

3. What products come from seeds that are of value as food for man?

4. In what condition must food material be in order to circulate in plant or animal bodies?

References

Hunter, *Essentials of Biology.* Chap. VI.
Hunter, *Elements of Biology.* Chap. VI.

PROBLEM XI

A study of the conditions (factors) necessary for awakening (germinating) the embryo in the seed.

I. FACTORS

a. Moisture

Method. — Place a layer of moist blotting paper in each of three cups. Put six soaked beans in each. Keep the seeds in one cup about half covered with water, keep those in the second just moistened, and keep those in the third dry. Keep the cups lightly covered, and put in a moderately warm place. Examine them daily for a week or so.

Observations. — Tabulate results as follows: —

NUMBER OF BEANS SPROUTED

DAY	DRY	MOIST	WET
First			
Second			
etc., to seven days.			

Conclusion. — What amount of water do you think is best for germination? Reasons?

b. Temperature

Method. — Plant equal numbers of soaked peas and beans in each of three germinating boxes or flower pots. Put one box in a warm place, where the temperature is above 80° F., another where the temperature is from 65 to 70° F., and the third where the temperature is at least below 40° F. See that all have the same conditions of air, light, and moisture. Observe them for a week or two.

Observations. — 1. Tabulate the daily observations as follows: —

Temperature	1st	2d	3d	4th	5th	6th	7th	8th
80 degrees and more .								
65–70 degrees								
30–40 degrees								

Conclusion. — What sort of temperature is best for germinating seeds? Reasons?

c. Oxygen

Method. — Fill a wide-mouthed bottle nearly full of moist sand. Put twenty soaked peas in this bottle, and seal it air-tight. Put as many soaked peas in a similar bottle, but leave uncorked. Observe results for a week.

Observations. — 1. Tabulate the daily observations as follows: —

Number of Peas Sprouted

	1st	2d	3d	4th	5th	6th	7th
Sealed bottle . . .							
Open bottle							

Conclusions. — 1. Do sprouting seeds need oxygen? Reasons for your answer.

2. What element have you learned is in the air?

3. What happens when oxygen combines with any other substance, as carbon or food?

4. Do germinating seeds need food? If so, what else do they need in order to set free the energy contained in the food? (See Prob. I, *b*).

5. What is one of the main reasons farmers plow and harrow the soil?

d. Food

(Some results of oxidation of food in both plants and animals.)

Method. — Germinate some seeds in a small, wide-mouthed bottle. After a few days remove some of the gas above the sprouting seeds with a large bulb pipette, and bubble it through limewater. Put a lighted splint in the gas still remaining in the bottle.

Observations — 1. What results when the gas was bubbled through limewater? When the lighted stick was inserted?

Conclusions. — 1. What gas was evidently present? Reasons for your decision?

2. Where was this gas evidently formed? Explain.

3. How have we heretofore learned this gas to be made?

4. If oxidation took place in the seeds, what else should result besides giving off carbonic acid gas?

5. Insert a thermometer among some germinating seeds, and also among a lot of seeds not germinating, but under similar conditions. Result?

6. How do the results obtained here agree with those of your previous study of oxidation?

7. Blow through a glass tube into some limewater. Result? What has evidently been formed in your body?

8. What are some of the results of oxidation of food in both plants and animals?

9. Explain how you know seeds must breathe.

References

Hunter, *Essentials of Biology*. Chap. VI.
Hunter, *Elements of Biology*. Chap. VI.

PROBLEM XII

A study of young plants until they are independent (seedlings).

Material. — Soaked beans and peas. Sand or sawdust, boxes or pots.

Method. — Plant the soaked seeds in pots or shallow trays, with holes in the bottom for drainage. Plant them in moist sand or sawdust. Use a box with glass side for studying root development. Keep the temperature about 72° F., and water them occasionally. Take out specimens from day to day until a complete series is obtained up to the time green leaves appear.

Make sketches of these changes every other day, for about two weeks. The series of sketches should show just what has become of each part of the embryo.

a. The Bean Seedling

Note. — A growing plant is called a *seedling* until it loses its seed leaves, or cotyledons.

Observations. — 1. Which part of the embryo breaks through the seed coats first? Where?

2. Into what does the hypocotyl develop?

3. What part appears first above ground?

4. Are the cotyledons of the bean pushed or pulled out of the ground?

5. What change takes place in the size of the cotyledons? Color?

6. What becomes of the cotyledons in old specimens?

7. What color has the part above ground?

Conclusion. — What does the change in size of the cotyledons indicate?

Drawing. — Draw a horizontal line across a sheet to represent the level of the sawdust or other material used. On this line make a series of 5 sketches, showing just what has become of the cotyledons, hypocotyl, and plumule. Label these parts.

b. Pea Seedling (Optional)

Observations. — 1. Can you find the same external structures in the pea as were found in the bean? Name them.

2. Remove the seed coat from a soaked seed. How many cotyledons do you find?

Note. — Plants whose seeds contain two cotyledons are said to be *dicotyledons.*

3. Find the hypocotyl and plumule. Are they located in the same place as in the bean?

4. Watch pea seedlings develop as with the beans. Which part comes above ground first?

5. What parts of the seedling remain below ground?

6. What becomes of the cotyledons?

Conclusions. — 1. How do the cotyledons of the pea differ in use from those of the bean?

2. What is the principal difference between bean seedlings and pea seedlings?

Drawings. — Make a series of sketches as with the bean seedling, showing the different stages of germination and just what becomes of each part of the embryo. Fill in the following table: —

	Part above Ground First	Parts Left under Ground	Fate of the Cotyledons	Fate of the Hypocotyl	Fate of Plumule
Beans . .					
Pea . . .					

c. Uses of the Cotyledons

Method. — Plant a few beans and peas in sawdust. After the cotyledons or leaves have appeared above the ground remove the cotyledons from half of each sort of seedling. Care for the seedlings and examine from time to time for ten days or so. What results?

Conclusion. — What is at least one use of the cotyledons of the bean plant? Of the pea?

d. The Corn Seedling (Optional)

Observations. — 1. Use soaked corn grains. Find a light-colored area on one side. This marks the position of the embryo. Is it large or small compared with the entire seed?

2. Cut a grain lengthwise through the narrow side, and find the embryo. Verify your opinion in the preceding topic as to the comparative size of the embryo.

3. Put some iodine solution on the cut surface. Results?

Note. — The embryo does not stain so deeply with iodine as the endosperm. Endosperm is food material *outside* the embryo.

4. Test for other food substances. Results ?

Conclusion. — Is most of the food matter of corn grains inside or outside the embryo ? What foods are present ?

Observations. — 1. Use a hand lens. Note that the embryo lies in such shape that the hypocotyl points toward the end that was attached, while the plumule points the other way.

Note. — The tiny plumule is attached to that part of the embryo nearest the pointed end of the corn grains, which has a single cotyledon. Plants having but one cotyledon, as the corn, are known as *monocotyledons.*

2. Sketch a section as cut above × 3. Label all parts studied.

Observation. — Remove the endosperm from some corn seedlings that have just germinated. Place on netting over water in a cup so that the roots reach the water. Place with them an equal number of corn seedlings with the endosperm present. Observe them for a number of days. Results ?

Conclusion. — What is the use of the endosperm of corn ?

PROBLEM XIII (Optional)

A study of some methods of plant breeding.

a. Seed Selection

Observations. — 1. In 1892 about 880 varieties of apples were on sale by American nurserymen. These were the result of seedlings coming up here and there by accident. If so many were produced haphazard, do you think better results might be obtained by careful selection ?

2. Sort over a number of bean seeds of any one variety. Examine numbers of ears of corn. Are they all exactly alike ? If not, how do they differ ?

3. Select the seeds you think would produce the better plants. Notice weight, color, size, shape, and number of kernels to the ear.

Conclusion. — Do you think it wise to carefully select seeds ? Give reasons for your selection in 3.

Note. — It is not sufficient to alone select what *appear* to be the best ears, but we must know which can transmit their good qualities in the highest degree, or find what is known as the "*hereditary percentage.*" Before this is done, the sprouting ability of the seeds should be tested, as follows :

b. Seed Testing[1]

1. Germination

Method. — Make a shallow wooden tray about $1\frac{1}{2}$ inches deep, 15 inches wide, and 23 inches long. Divide the tray into small spaces about $1\frac{1}{2}$ inches square by a checkerboard lacing of twine across the top. Fasten the twine by tacks, and number the rows in both directions on the sides of the tray. There should now be about 10 rows of squares the narrow way and 15 the other, as in Figure 11. Before finally lacing to form the squares, loosely fill the tray with dry sand or sawdust. Soil may be used, although not so clean to handle.

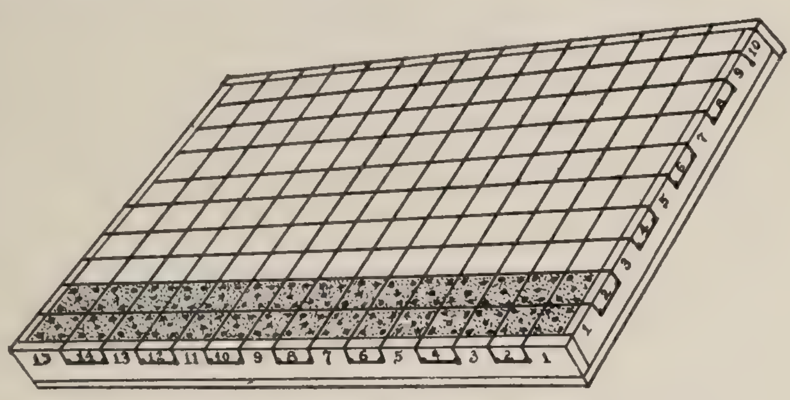

Fig. 11. — Seed testing frame. (After Howe.)

Arrange ears of seed corn in rows of ten to correspond with the ten rows of squares, or carefully label each ear to correspond with a certain square. Arrange the ears on shelves, where they will not be disturbed until after the test is completed.

When ready to begin the test, take ear number one, and carefully remove five kernels from each ear. (The kernels from the tips of each ear should not be used.) Take kernels of average size, removing them in a spiral manner around and lengthwise of the ear, from about one inch of the base of the ear and one inch of its tip. Plant each of these five kernels in the square which corresponds with the ear from which they were taken. Push a kernel in each of the four corners of the square point downward, and the fifth in the middle. Push all to a uniform depth, just far enough to be covered with sand when the forefinger is withdrawn.

After the planting is completed, lay a small piece of paper flat on the tray and pour water on the paper until the sand is thoroughly saturated. Put the tray in a warm place and keep the sand watered until the young shoots are an inch or so high.

Observation. — Examine the squares in regular order and carefully note the condition of the young seedlings. Tabulate your results, showing the number in a square in good condition and the number in poor condition.

Conclusions. — 1. If all five plants of a square are thriving and sturdy, what is your decision concerning the ear from which these seeds came?

2. Suppose two or more of them are shorter, or look pale and sickly. What about the chances concerning the ear from which they came?

[1] Adapted from Howe, Circ. 96, U. S. Dept. Agri., 1910.

3. Suppose there are four good plants, but the fifth is smaller, or cannot be seen at all. Dig down carefully and see if the kernel germinated, but with its tip held in place by the tough skin of the kernel. What is your conclusion?

4. Suppose one kernel out of the five has not even sprouted, while the other four are an inch or so high. Conclusion?

5. Which is more likely to cause a poor early showing in the field, — crows, cold weather, or poor seed?

6. Show why seed corn should not be purchased already shelled.

7. Why is it unwise to use the kernels at the tip of the ears? Give at least two reasons.

Problems

1. How many hills of corn in an acre if the hills are 3 ft. 6 in. apart?

2. How many kernels needed to plant an acre at three kernels to a hill?

3. How many kernels in an average-sized ear you are testing? How many ears of the sort you are testing to plant an acre?

Note. — Fifteen ears of good size, at three kernels per hill, should suffice for an acre.

4. How many acres can be planted with the seed corn tested in one tray?

Note. — Pupils may well test the germination of seed corn which their fathers expect to use, wherever conditions permit. If their fathers are not using seed corn, pupils may well offer to do this for neighboring farmers. The ears to be tested should be carefully numbered, five kernels taken from each by those doing the testing and arranged in small envelopes or packets, numbered to correspond with the ears. When the test is finished, send the numbers of the poor ears back to the farmer, that he may know just what ears to reject.

2. Percentage of Germination

Method. — A simple seed tester may be made out of two shallow vessels, such as pie tins, and blotting paper or cloth. Cut the blotting paper or cloth so as to fit the bottoms of the vessels. Heat the blotters in an oven or boil the cloths in order to kill any germs that may be present. Place a blotter or cloth in the bottom of one of the shallow vessels, wet it, and place one hundred soaked radish or clover seeds upon it. Cover these with another wet blotter or cloth, and place the second vessel on the other as a cover. A glass plate may perhaps serve better as a cover. See that the rims fit well. Set aside in a good growing temperature.

Observe the seeds from time to time and remove all that have germi-

nated. When all have germinated that will, subtract the number remaining from one hundred.

Note. — Suppose 20 seeds out of the 100 failed to germinate. Of course 80 germinated, or 80% of the sample. This is known as the *percentage of germination.* This may be calculated with 50 seeds, but the likelihood of error will be greater. Why?

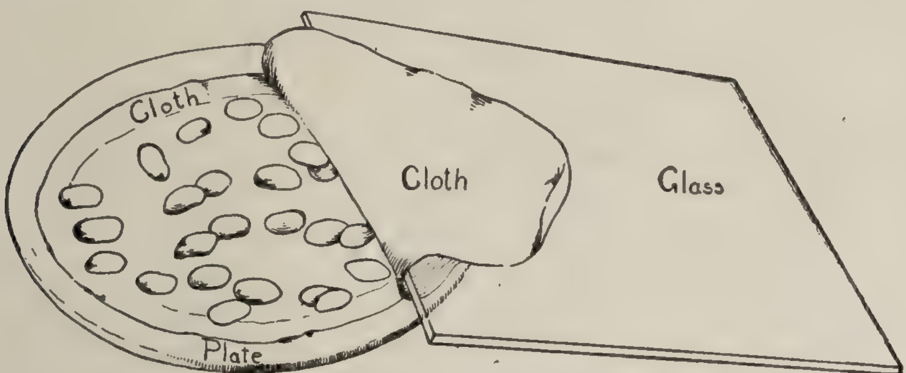

FIG. 12. — Simple seed tester.

Observation. — Place 100 radish or clover seeds in a home-made tester. Remove those that germinate from time to time. How many remain?

Conclusions. — 1. What is the *percentage of germination* of the seeds tested?

2. Why is it especially important that seeds, as clover, be tested for percentage of germination before planting?

Given several kinds and grades of any certain sort of seed on sale, how would you finally decide on which to buy? Should high-priced seeds be tested before or after buying?

Note. — Very valuable aid may well be rendered neighboring farmers and gardeners by pupils in thus testing seeds which are to be used for crop raising. Peas, beans, corn, cucumbers, melons, oats, wheat, barley, etc., as well as the common garden seeds, may thus be easily tested.

3. — Large Seeds versus Small Seeds[1]

Observations. — 1. Plant a few beans an inch deep in jar 1; a few clover seeds an inch deep in jar 2, the same number of clover seeds a quarter of an inch deep in jar 3. Set them aside in good growing surroundings, and note results daily until the seedlings are well developed.

2. Compare jars 1 and 3. Which plants develop the more vigorously? Which pushed through the greater amount of soil. Which seeds are the larger?

[1] Adapted from Goff and Mayne, *First Principles of Agriculture.*

3. Compare jars 2 and 3. Which plants are the most vigorous? Which pushed through the greater amount of soil?

4. What is shown in Figure 13?

Conclusions. — 1. How is the *size* of seeds related to the early seedling?

2. What relation between the size of seeds and depth of planting? Explain.

1 2 3

FIG. 13. — Large *versus* small seeds. Jar 1, navy beans planted one inch deep; jar 2, clover seeds planted one inch deep; jar 3, clover seeds planted one quarter inch deep.

3. Give at least three reasons why farmers should reject small and shrunken kernels of corn.

4. What precautions should usually be observed in selecting seed?

c. Hereditary Percentage, or the Number of Offspring that Inherit Desired Characters

Observation. — After the sprouting power of the seeds is determined, the seeds from particular ears are planted in particular rows, so that the offspring of these ears can be compared.

Conclusions. — 1. The poor and barren stalks are now removed before the tassels appear. Why?

2. Why should this testing lot be separated a mile or so from other fields of corn?

3. In the autumn the best ears are now selected for next year's crop. These selections depend upon the line of improvement desired.

4. Suppose an *increased yield* is desired. What results from culling the barren stalks? When should they be culled?

5. Suppose *quality*, such as a greater percentage of oil, is desired. Test a kernel for oil. What part contains most of the oil? How should you select ears to develop this quality? What does the white part of the kernel contain? How select to develop this quality? What is most of the rest of the kernel around the germ? How develop this quality?

6. Suppose you wished to develop, *size*, *shape*, *color*, etc. How develop these qualities?

7. It may be desirable to select a sort that is *hardy* and *ripens early*. The original home of corn was in Central America. How develop hardiness and early ripening ability?

8. Can corn now be grown on the great alkali plains? How might a race of corn resistant to drought be produced?

9. A great amount of damage is annually done by corn smut. How might a resistant variety be produced? See Hunter, *Essentials of Biology*, p. 81.

d. Artificial Cross-pollination

Observations. — 1. Tie up a tulip or lily flower bud about ready to open with a manila bag, so that there will be no danger of foreign pollen being transferred there by bees, wind, or other foreign agents.

2. Remove the corolla and stamens entirely from the pistil of another tulip or lily bud of *another sort*, being careful to cut the stamens away before the flowers have opened, thus leaving the pistil alone on the receptacle. (Cut at the line marked "W" in Figure 14.)

3. As soon as the blossom in the bag opens, transfer some of the pollen to the stigma of the flower without stamens. This is best done by crushing a ripe anther upon the finger nail, and then transferring it to the stigma by means of a small scalpel made by hammering out the pointed end of a pin. A camel's-hair brush may also be used. See that the stigma is entirely covered with pollen. Label the stigma thus pollinated, stating the date, from what pollinated, etc.

FIG. 14. — Showing how to cut away the stamens and corolla of a blossom, for artifical cross-pollination. (After Bailey.)

Conclusions. — 1. If pollen is transferred from one flower to another flower of another variety, it is termed cross-fertilization. Why?

2. Why cut away the anthers from one of the flowers? Why inclose the other in a paper bag until it is ripe?

Observations. — 1. After the pod or fruit of the pollinated flower starts to grow, remove the bag. Permit the fruit to ripen. Does it differ from either of the fruits of the parent plants?

2. Try ripening the fruits and planting the seeds, in order to determine the effect of the cross-pollination.

Note. — Methods similar to the above are in use by Burbank and others in producing new varieties of fruits. Such processes are part of the work of plant breeding.

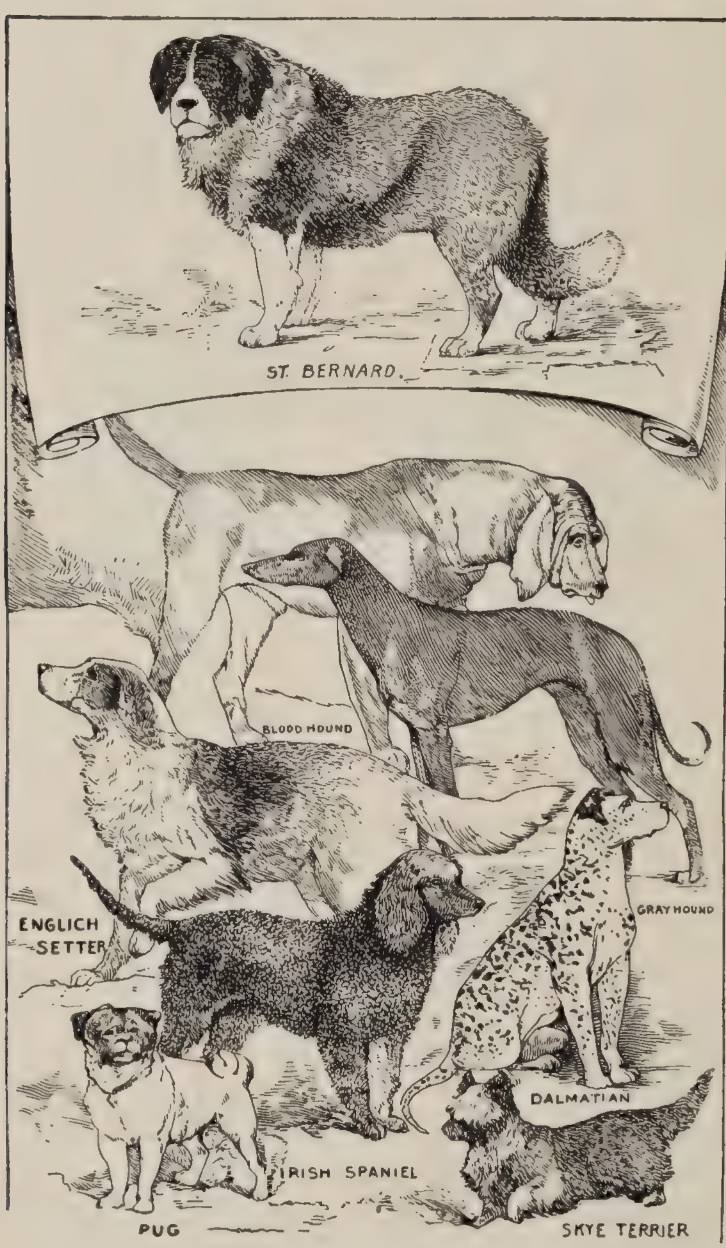

Fig. 15. — Artificial selection among dogs. (After Romanes.)

e. Comparison with Animals

Observations. — 1. Study Figure 15. Which of the dogs is specialized for speed? Driving cattle?

2. Which is especially prized for stopping cattle? Trailing by scent? Finding game? Drawing vehicles? Going into holes? Cold weather? House pet?

3. A hairless dog is much prized in hot climates, as in Mexico, etc. Why?

Conclusions. — 1. It is claimed that widely differing environments under various forms of domestication cause sports. What do you think is meant by such a term? Are they accidental or designed by man?

2. What advantage are these sports to breeders?

Note. — Professor De Vries has shown, by cultivating American evening primroses in Europe, that such sudden changes in environment may cause not only varieties but new species to be formed. It is supposed that all varieties of dogs thus originated from the wild dog, all varieties of apples from a wild crab apple, and all varieties of pigeons from a wild pigeon, etc.

Questions

1. What is a seedling?
2. Why are the cotyledons often called "seed leaves"?
3. What is the main use of the cotyledons of the bean?
4. What is the use of the endosperm of corn?
5. Give some of the methods used in plant breeding.
6. What are hybrids? How are they commonly formed?
7. Who is Burbank, and what has he done?
8. What is meant by the term heredity?
9. Explain the statement by Cornwall, "Nature ever yields reward to him who seeks and loves the best."
10. Why is plant and animal breeding of the highest importance to a nation?
11. What is meant by the term hereditary percentage?
12. How compute the percentage of germination of seeds?

Special Reports

1. Corn, and its use in making alcohol.
2. Barley and beer making.
3. Burbank and his work.
4. Some new plant creations.
5. Plant breeding.
6. Any newspaper or magazine articles pertinent to your studies.
7. The United States Government plant-breeding laboratory.
8. Corn culture and breeding.

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PROBLEM XIV

A study of the structure and work of roots.

Materials. — A number of bean, pea, and corn seedlings. [1] A pocket garden.

Root Systems

Observation. — Carefully wash the roots of the bean seedling. Find a long main root (*primary root*) that is but a continuation of the lower stem. Find other roots (*secondary roots*) that are branches of the primary root. Other small branches (*rootlets*) may also be readily seen. Do the roots all take one general direction?

Conclusions. — 1. What reason can you give for the arrangement of roots as you find them?

2. Why do roots not have such a definite shape as the stem?

a. Factors influencing Direction of Growth

1. Effect of Gravity

Note. — The pulling force of the earth is known as the force of gravity.

Observation. — Sprout some seeds in a pocket garden until the roots are a half inch or so in length, then turn the garden one fourth way around and examine again in a day or so. Results? A growing plant in a pot may also be inverted and the effect on the stem and roots noted.

[1] A pocket garden may be made as follows: — Get a couple of 4 × 5 negative plates, clean them, and cut 5 pieces of blotting paper about ¼ inch smaller than the glasses. Lay the blotters on one of the plates, and cut four ¼-inch strips of wood so as to just fit on the glass outside the blotters. Moisten the blotters, place some well-soaked seeds of mustard, barley, or radish on them, cover the seeds with the other glass, and bind the glasses together with bicycle tape.

Conclusion. — What influence do you think the force of gravity has on roots?

2. Effect of Moisture

Observation. — Plant soaked mustard or radish seeds on the outer side of a moist sponge and suspend it under a bell jar where there is plenty of light and moderate temperature. Observe results.

Conclusions. — 1. What effect does moisture have on growing roots?

2. Which influence seems to be the more powerful, moisture or gravity?

b. Structure

1. Root Hairs

Method. — Sow radish seeds on moist earth in a pan, or next to the glass sides of a funnel, so that as the rootlets develop, they may be seen. Or, put a cutting, as tradescantia, in a bottle of water, and note the fine fuzzy growths on the rootlets.

Observations. — 1. Find fuzzy, hairlike whitish structures on the rootlets. They are called *root hairs.* Where are they the longest? Where the most abundant?

2. Examine them with the low power of a microscope. Are their walls thick or thin?

Conclusions. — 1. Tell fully just what you think is the purpose (function) of root hairs.

2. Why should root hairs be thin?

Note. — Root hairs increase the absorbing surface of roots from 50 to 100 times.

2. Fleshy Roots

Method. — Cut a cross section through a fleshy root as a carrot or parsnip (*taproot*) and dip in iodine. Also cut a lengthwise section, and stain.

Observations. — 1. What part is stained the most, the outer part (*cortex*) or the inner part (*central* or *woody cylinder*)?

2. Find some small whitish branches or cores of wood run-

ning from the woody cylinder towards the surface through the cortex. These connect with the root hairs on the rootlets, and are modified cells that form continuous hollow tubes. They are known as *fibrovascular bundles.*

3. Examine figure of a cross section of a taproot (Fig. 16). Note that the root hairs are but hollow extensions of cells (epidermal cells) on the outer margins of roots or rootlets.

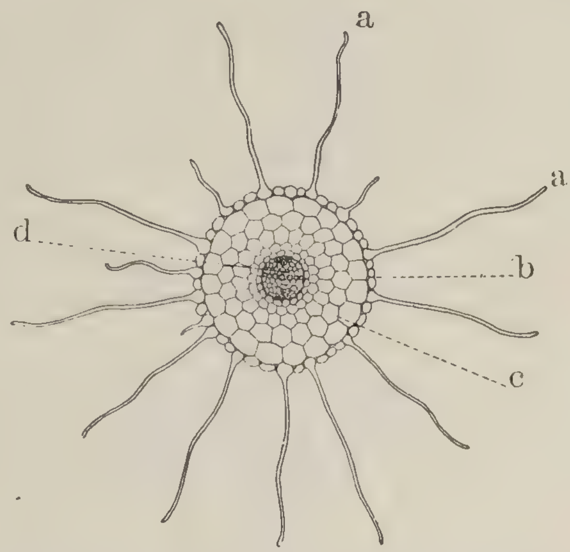

FIG. 16. — Cross section of young root. *a*, root hair; *b*, epidermis; *c*, cortical layer; *d*, fibrovascular bundle.

Conclusions. — 1. Which part of a taproot contains stored-up food (starch)? Explain your answer.

2. What seems to be the use of fibrovascular bundles in roots?

c. Root Hairs (Optional Home Work)

Observations. — 1. Remove a geranium or other plant from the soil. Pull the roots bearing root hairs through the hand in such a way that the root hairs will be injured. Also allow some of them to dry. Repot the plant and water it. Note the effect after a few hours. After a day or so.

2. Remove and repot another similar plant, taking care to keep root hairs moist and uninjured. Water it. Note the effect as above.

3. Which plant wilts more than the other? Sooner than the other?

4. Do both plants regain their normal condition at the same time?

Conclusion. — What do you conclude is one function of root hairs?

d. How Root Hairs absorb Soil Water

1. Osmosis and Root Hairs

Note. — The process by which two fluids or gases separated by a membrane pass through the membrane and mix is called *osmosis.*

Method. — Make an artificial root hair by emptying the con-

tents of an egg through a small hole at one end; place the shell in a tumbler and cover with weak hydrochloric acid or vinegar. (Fill the shell with water so that it will sink.) When the shell is dissolved away, fasten the membrane to a $\frac{1}{4}$-inch glass tube as shown in Figure 17, by using a few turns of string or a rubber band. Place it under water and blow gently in the

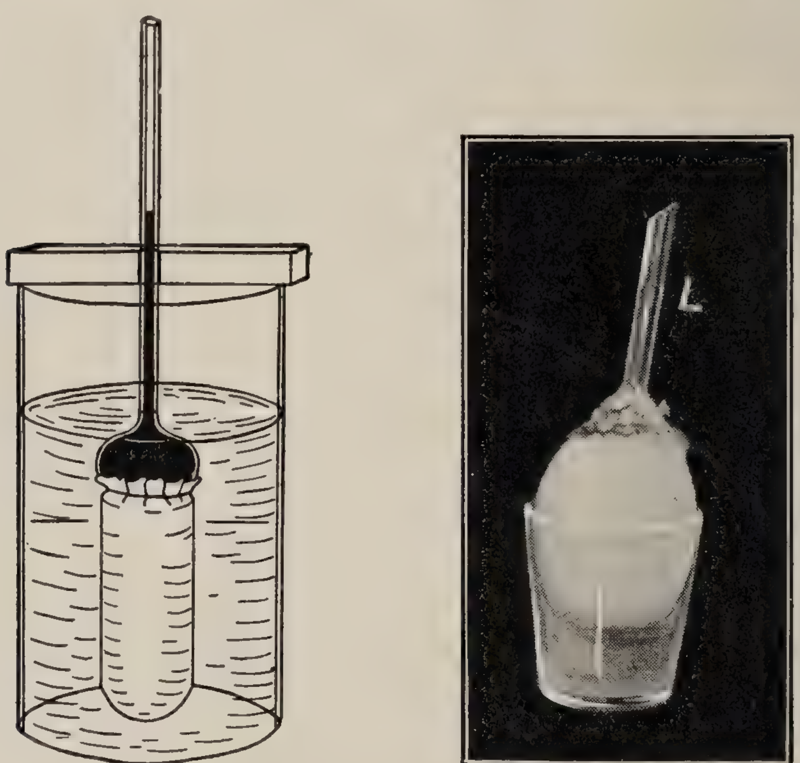

FIG. 17.—Experiments to show osmosis.

tube to see if there are any leaks. If there are none, pour into the tube enough strong sirup (made of glucose and water) to fill it to a point a little above the membrane. Submerge in water, as in Figure 17, so that the two liquids are at a level. The membrane may well represent a root hair, or cell, and the glass tube one of the tubes of a fibrovascular bundle of a root.

The experiment may be varied by setting it up as in Hunter, *Elements of Biology*, page 89. In many respects this is preferable, as the white of an egg is much like protoplasm or the living matter in cells.

Artificial root hairs may also be made by pouring a small amount of celloidin or of collodion in a $\frac{1}{2}$-dram tube-vial and tipping it about so that the contents are hardened into a thin

layer within the vial, and then removing it and fastening it to the glass tube as for the egg membrane. Or fasten it to a rubber stopper into which a glass tube has been inserted.

Observation. — Are there any changes in level in the two liquids? Which one, if any?

Conclusions. — 1. Has the water in the jar penetrated the membrane? How do you know?

2. Has any glucose passed through the egg membrane into the water? (Test the water in the tumbler with Fehling's solution for an answer.)

3. If time permits, try making the liquid in the tumbler denser than that in the membrane, and see whether the exchange is now more rapid in the opposite direction. Is the greater flow towards or away from the thicker (denser) fluid?

4. How do roots get water and soluble salts from the soil?

5. Show how such substances would likely be forced up in the stem.

6. Why should the soil where seedlings are growing be mellow, or loose and porous?

7. Expose a pot of wet soil to the direct action of the sun for a few days. Do likewise with another pot of soil but cover it with loose grass or straw to form a *mulch.* Which pot has the most porous soil at the end of the period? Which sort of soil will remain the more porous — that naturally covered with grass, leaves, etc., or *mulched*, or that exposed to the direct rays of the sun? Show how one sort of soil needs breaking up or *tilling* more than the other.

8. Why is it that plants need fine loose soil for their root hairs?

9. Why do plants wilt when first transplanted, and later recover?

10. Show how liquid foods might get from food tubes into near-by blood tubes.

11. Show how oxygen of the air might get from the lungs into near-by blood tubes.

Questions

1. Why should a farmer cultivate or till the soil?

2. What is the purpose of mulching the soil?

3. How deep has the mesquite or sagebush been known to send its roots after moisture? Where does it grow?

4. What harm would likely result to trees if the paving and sidewalks should be built up closely about them?

5. Would potted plants be likely to thrive well if the hole in the bottom of the pot was kept plugged up? Explain.

6. Explain the truth of the following: "Perfect agriculture is the true foundation of trade and industry, — it is the foundation of the riches of states."

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PROBLEM XV

A study of some of the relations between roots and the soil.

a. Origin of Soil

1. Mineral Matter

Method. — Put some iron tacks in enough water to cover about half of them. Set aside then and observe them for a few days.

Observations. — 1. What has happened to the tacks?

2. Examine some sand with a hand lens. Also examine some soil in the same way. What do you observe?

Conclusions. — 1. Could other minerals be affected in the same way as the iron? What would be the result?

2. Show how iron might become a part of the soil.

3. How does freezing and thawing affect soil and rock?

4. What happens when glaciers grind rock against rock?

5. What happens when waves dash against rocks? When water runs swiftly over rocks?

6. Summarize the various sources of mineral matter in soil.

2. Organic Matter

Observation. — Examine some loam and soil collected from beneath trees.

Conclusion. — What else evidently constitutes part of the soil? Reasons.

b. Kinds of Soil

Method. — Take a pound of rich mold from under forest trees, a like amount of rich loam from beneath this mold (black soil), and the same amount from a barren roadside or field. Dry them. Place them on a pie tin or piece of sheet iron, and heat them red hot over a gas stove or coal fire until all that will burn seems to be burned up. Reweigh each sample. Put what remains in bottles and give them to the school museum, if you desire, after labeling them.

Observations. — 1. Tabulate results as follows: —

	Rich Mold	Black Soil	Barren Soil
Original weight			
Weight after burning			
Loss in weight			

2. Note the final appearance of the samples.

Conclusions. — 1. What do the losses in weight indicate?

2. Which sort of soil is richest in organic matter? Inorganic matter?

c. Water-retaining Ability of Soil

Method. — Take $\frac{1}{4}$ pound each of gravel, sand, barren soil (clay), rich loam, leaf mold, and $\frac{1}{16}$ pound of dry leaves.

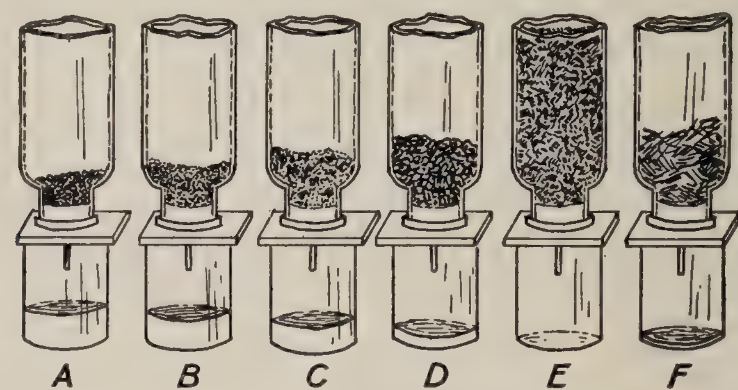

FIG. 18.—Experiment to show kind of soil which best retains water. *A*, gravel; *B*, sand; *C*, barren soil; *D*, rich soil; *E*, leaf mold; *F*, dry leaves.

Thoroughly dry before weighing. Now place the samples as shown in Figure 18, shake them down, and slowly pour $\frac{1}{4}$ pint of water on each.

Measure all that runs through and tabulate results as follows: —

Observation. — Amount of water left in soils.

	GRAVEL	SAND	CLAY	RICH LOAM	LEAF MOLD	LEAVES
Amount of water added . .						
Amount of water caught . .						
Amount left in soils . . .						

Conclusions. — 1. In which sorts of soil would roots best get their water supply?

2. Is the forest floor of leaves and loam of any importance in retaining the water of rain or snow? Explain.

3. What would likely be the character of the water drained from such forest floors?

4. What is indicated by muddy streams? By the muddiness of the Missouri River?

5. What sort of soil permits of the most rapid evaporation of water?

6. What is the main cause of many million dollars worth of expense to the governments and cities in dredging out and repairing harbors? How might much of this expense be saved?

7. What is the main cause of dry springs and wells in many districts?

8. Why is it important that the regions of the sources of streams and rivers be forest clad?

9. What is the main cause of many disastrous floods and freshets?

d. Necessity for Organic Matter

Method. — Fill three pots, one with clay subsoil, the second with fertilizer, and the third with humus. Plant some corn or barley in each. Give equal light and care and observe the growth from time to time.

Observation. — Which shows the most vigorous growth after two weeks' time?

Conclusions. — 1. What is the relation of humus (organic matter) to the growth of plants?

2. What is one of the necessary conditions for a fertile soil?

e. Necessity for Mineral Matter

Method. — Partly fill four quart fruit jars, one with distilled water, the second with nutrient solution[1] without calcium phosphate, the third with nutrient solution without ferric chloride, and the fourth with nutrient solution. Place bean or corn

[1] A nutrient solution known as Sach's Solution may be made as follows: —

Potassium Nitrate	1.00	gram
Sodium Chloride	0.50	gram
Calcium Sulphate	0.50	gram
Magnesium Sulphate	0.50	gram
Calcium Phosphate	0.50	gram
Ferric Chloride	0.005	gram
Distilled Water	1000.00	grams

Add the ferric chloride at the time the solution is to be used, by adding a drop or so to the solution in the bottle used for the seedlings.

seedlings in the jars so that their roots extend down into the liquids. Or better, put cuttings of tradescantia in the liquids. Observe the growths for two or three weeks.

Observation. — Which jar shows the most vigorous growth?

Conclusions. — 1. What else do plants need besides water, air, moderate temperature, and organic matter (humus) in order to live?

2. Write a paragraph summing up the factors that make soil fertile.

1. Another Use of Root Hairs (Optional)

Method. — Grow a number of radish seeds in a pocket garden. Place a sheet of blue litmus paper so that the growing roots will lie against it.

Observation. — Observe them from time to time. Does any change of color take place? If so, what?

Note. — Blue litmus paper will turn red whenever an *acid* comes in contact with it, while red litmus paper will turn blue whenever an *alkaline* substance comes in contact with it. (The instructor should here demonstrate these changes.)

Conclusions. — 1. Do root hairs give off an acid or alkaline substance? Explain.

Note. — Many mineral substances are dissolved by the action of an acid, as carbonic acid in the soil, from roots. The minerals mentioned in the formula for making nutrient solution are some of them, such as calcium, iron, sodium, etc.

2. Try dissolving some calcium phosphate in distilled water. Result? Now add a few drops of hydrochloric acid or sulphuric acid. Is there any difference in result? What?

3. See if you can now tell another indirect use of root hairs.

f. Root Tubercles

Method. — Carefully remove the roots from a clover plant, or alfalfa, or vetch. If these cannot well be obtained, use a well-developed bean seedling. Wash the roots carefully. When they are dry, look for nodules, or small wartlike growths on them.

Observation. — Describe the appearance of the nodules. Where are they located?

Note. — Root tubercles are small, knotty, wartlike growths that form on the roots of such plants as clover, vetch, alfalfa, pea, bean, cowpea, soja bean, etc. These tubercles are the homes of germs or bacteria. Their life activities enrich the soil by the addition of much-needed nitrogen, which these germs obtain from the air and store in their root homes. Plants are unable to obtain nitrogen from the air without their aid, although, as we have learned, the air is about four fifths nitrogen. Humus, manures, and decaying organic matter contain nitrogen in such shape that plants may use it. But these are sometimes difficult to get, and are relatively expensive.

FIG. 19. — Roots of red clover with nodules which are the homes of bacteria which enable the plant to use the nitrogen of the air.

Conclusion. — What should be done by farmers and gardeners in order to increase the supply of available nitrogen in the soil? What are the advantages of this method?

g. Effect of Crops on Soil

Observation. — Copy Figure 20 in your notebook, using different colored crayons, if possible, to represent the phosphoric acid, potash, and nitrogen. This and the two following diagrams show the amounts of phosphoric acid, potash, and

nitrogen removed from the soil by 1000 pounds each of the different crops mentioned. Each square indicates a pound.

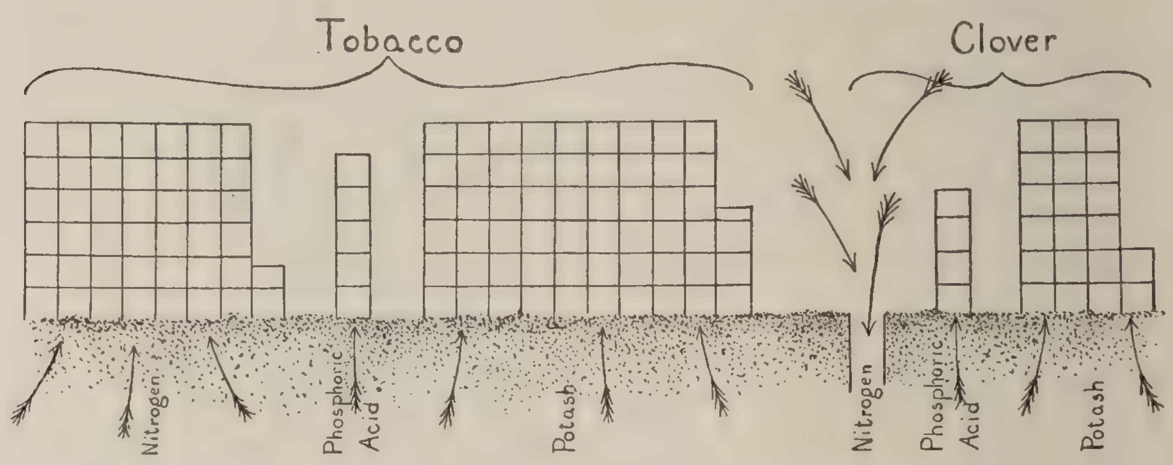

FIG. 20. — Showing the pounds of plant food removed by 1000 pounds of Virginia leaf tobacco, and by 1000 pounds of clover.

Conclusions. — 1. How does clover compare with tobacco as a user of nitrogen?

2. If 1000 pounds of average barnyard manure contains about 5 pounds of nitrogen, how much manure will be required to replace the nitrogen removed by 1000 pounds of tobacco?

Observations. — 1. Which of the crops shown in Figure 21 reduce soil fertility the most rapidly?

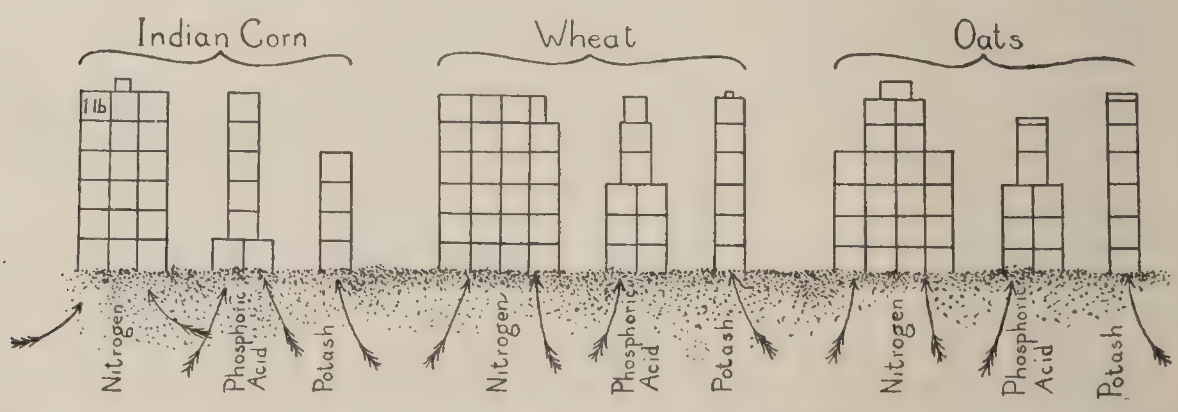

FIG. 21. — Showing the amounts of the three most important plant foods that are removed from the soil by 1000 pounds each of the grain of Indian corn, wheat, and oats.

2. How many pounds of nitrogen are removed by 1000 pounds of each of the three crops shown?

3. How does the amount of nitrogen removed compare with the amounts of the other substances?

Conclusion. — Compute the amount of manure necessary to offset the nitrogen removed by each of the grains mentioned.

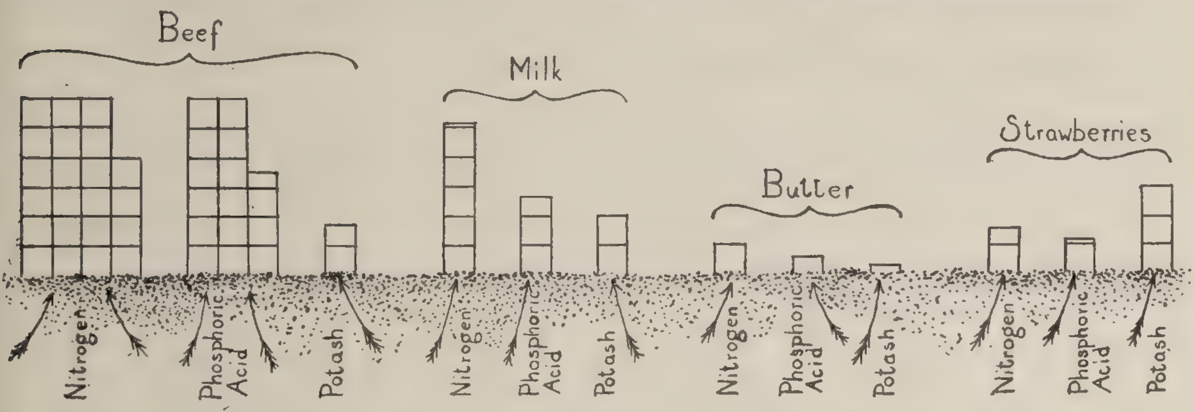

FIG. 22. — Showing the amounts of nitrogen, phosphoric acid, and potash removed from the soil when 1000 pounds each of beef, milk, and butter are sold.

Observations. — 1. How does beef compare with wheat as a remover of nitrogen?

2. How does dairying compare with crop raising as a remover of nitrogen?

Conclusions. — 1. As a rule, which do you consider the more expensive operations, — crop raising or dairying?

Note. — We must remember that total costs depend on the amount of plant food removed, the labor required, and the market price.

2. Suggest two means of returning nitrogen to soil that has been exhausted by repeated crops of the grains.[1]

h. Crop Rotation

Observations. — 1. What would be the advantage of planting rows of cowpeas between rows of corn after the corn no longer needs cultivating?

2. Many farmers plow grain stubble under in the autumn, and immediately plant some tubercle-bearing plant. Explain.

[1] Supplies of nitrogen bacteria may be obtained for experimental purposes by applying to the United States Department of Agriculture, Washington, D.C. Directions for carrying on the experiments accompany the supplies.

Conclusion. — Show why it is important that grain crops alternate with tubercle-bearing crops.

Note. — A regular order of crops, commonly including some tubercle-bearing crops, is known as *crop rotation.*

Observations. — 1. Study the following four systems of crop rotation and see if you can justify them.

	1st Year	2d Year	3d Year	4th Year	5th Year	6th Year	7th Year
a	Clover	Potatoes	Winter Wheat	Clover			
b	Corn	Corn	Wheat or Oats	Timothy and Clover	Timothy and Clover	Timothy and Clover	Corn
c	Corn	Oats	Wheat	Timothy and Clover	Timothy and Clover	Corn	
d	Potatoes	Corn	Corn	Clover and Grass	Clover and Grass	Clover and Grass	Potatoes

2. Which crops are nitrogen gatherers? Which for cash income?

3. Why is it that tubercle-bearing crops will grow where ordinary grain and garden crops fail?

Conclusion. — Explain fully just what is meant by crop rotation. Why is it of supreme importance to man?

Questions

1. Name some roots of commercial importance. Why are they important?
2. Why do some plants store up food in their roots?
3. What are water roots? Air roots?
4. What are parasitic roots? Give examples.

5. How are the roots of such plants as the dandelion and rhubarb protected from animals?

6. What insect damages the roots of the grape in Europe?

7. What are the advantages of tilling the soil?

8. What sort of soil is favorable to evaporation?

9. What is the relationship of tubercle-bearing plants to man's supply of food?

10. What results from the congestion of population in cities?

11. Why does such a man as J. J. Hill plead that the people "go back to the soil"?

12. Give a method of analyzing soils.

13. What compound of nitrogen is washed into the soil from the air by rains and snows?

14. What is mulching, and why is it done?

15. Why should the top layer of soil be loose where crops are growing?

16. Why are the grain crops relatively expensive crops for the farmer to grow?

17. What else do plants need from the soil besides nitrogen? What acid in the soil aids plants in absorbing these substances?

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PROBLEM XVI (Optional)

A study of buds and their relation to the growing plant.

Materials. — Winter branch of horse-chestnut, lilac, or similar plants. Brussels sprouts or cabbage. Winter branches of horse-chestnut or lilac in water in a moderately warm room.

a. Buds

Observations. — 1. Where do you find buds located?

2. Where are the buds the larger, — along the sides (lateral buds) or at the tip (terminal buds)?

3. How many terminal buds on the end of the stem of the horse-chestnut? Of the lilac?

4. Find scales on the outside of the horse-chestnut buds. Remove them. Describe their appearance and arrangement. Describe the appearance of the stem where they were removed.

5. Find a ring of scars just below the buds.

Conclusions. — 1. What seems to be the purpose of the sticky material on the bud scales of horse-chestnut ?

2. What do you think the old ring of scars represents ? The new ring of scars ?

3. Of what use is the overlapping of bud scales ?

Observations. — 1. What is the appearance of the inner part of the bud ?

2. Where are the inner parts of the bud attached ?

Conclusions. — 1. What structures are contained in the bud ?

2. What is gained by having these structures well developed in the bud ?

3. How do the structures stowed away in the horse-chestnut bud compare with those in the lilac ? What is the object of the rolling or folding ?

4. Why are the buds that live but one year unprotected ?

5. Would tropical trees be as likely to have buds protected as those in colder regions ? Explain.

6. Why do most of our common plants have buds ?

7. What would happen if a plant had no buds ? Explain.

Observations. — 1. Examine the opening buds of the winter twigs previously placed in water. What do you find ?

2. Find fresh scars. What do they represent ?

3. Cut a Brussels sprout or a cabbage head lengthwise through the middle. Explain what you see. Are there any protecting scales ? Is there a stem ?

Conclusions. — 1. What structures are contained in the bud ?

2. Why are buds of plants that produce seeds the first year and then die, unprotected ?

3. Name some buds useful as food.

PROBLEM XVII

The structure and work of stems.

Note. — A stem is a developed bud.

a. External Structure of a Dicotyledon (Optional)

Materials. — Stems of horse-chestnut, lilac, etc.

Observation. — Find leaf scars or traces above the buds, along the sides of the stem. What do they represent ? Do you find small scars here arranged somewhat horseshoe-shaped ? If so, they are the broken ends of the hollow tubes (fibrovascular bundles) mentioned under the study of root hairs. We found them to originate in the root hairs, from

whence they run up through the stem to the leaves, where they spread to form the veins of the leaf. They conduct fluids containing dissolved food matter from the roots to the leaves, and from the leaves to the stem and root. These tubes are closed when the leaves fall in the autumn. Can you tell why?

b. Lenticels

Observation. — Look for small openings or cracks in the bark (*lenticels*). These permit the passage of air, and are therefore breathing holes through the bark. Are there few or many?

Conclusions. — 1. If there are also breathing holes in the leaf, when are the lenticels of most importance to a plant?

2. Would there probably be as many lenticels in evergreen or tropical plants? Explain.

c. Internal Structure of a Dicotyledon

Observations. — 1. Cut a cross section of box elder or horse-chestnut twig, or other similar stem. How does the inner part (*pith*) differ from the circle bounding it (*wood*)?

2. Which is the stronger, pith or wood? Which is the most porous?

3. Find lines radiating from the pith through the wood (*medullary rays*). These serve as channels of communication between the pith or wood cells and the cells of the outer portion of the stem — even the lenticels. They thus convey oxygen as well as food (sugar and water) to the interior of the stem.

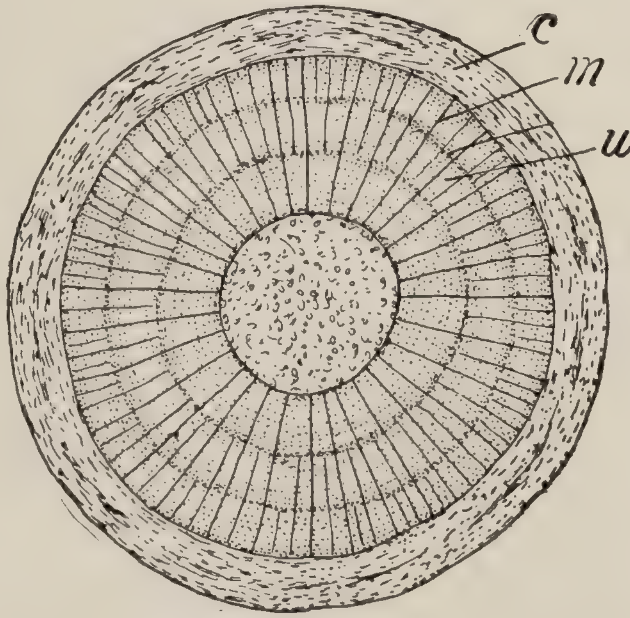

FIG. 23. — Cross section of twig of box elder three years old. Note three annual growth rings in the vascular cylinder. *c*, cortex; *m*, medullary or pith rays; *w*, wood. (After Coulter.)

4. Just outside the wood, find the bark. Strip off a bit of it. Can you find fibrous structures

(*bast*) (best seen in old bark)? Just outside this may be found the *rind* or *cortex*. In most stems this is made up in part of an outer layer of *cork*.

Conclusions. — 1. Can you think of any use for the woody part of the stem?

2. Review the function of the medullary rays.

3. (*Home work*) A potato is an underground stem. How can you tell? Select two potatoes of unequal weight. Peel one of them until it weighs as much as the other. Set both in a warm place, and after a day or so reweigh. Results? What is one of the uses of the epidermis of a stem? Would the corky layer do likewise?

d. Circulation in Stems

1. The Upward Path of Raw Food Material

Observation. — Get an entire plant with a taproot, as a parsnip. Cut off the root tip, and place the cut end in a solution of red ink or eosine. Let it stand a number of hours and observe the cut end. Cut various sections of the root and stem and see if you can trace the path of liquids to the leaves. Try the same with sections of a corn stalk.

Conclusion. — Where are the tubes (fibrovascular bundles) through which liquids rise situated?

Note. — A stem with fibrovascular bundles arranged as in the box elder or horse-chestnut is characteristic of plants with two cotyledons in the seed (*dicotyledons*). Stems with these bundles scattered through the pith as in the corn are characteristic of plants with one cotyledon in the seed (*monocotyledons*).

2. The Downward Path of Raw Food Material

Note. — Start this experiment two or three weeks ahead of the time needed.

Observations. — 1. Place some fresh willow twigs in water until they form roots. Girdle them (remove rings of bark about

$\frac{1}{2}$ inch wide) about one inch from the cut end. Observe results for several days.

2. What happens just above the girdle? What effect on the roots below the girdle?

Conclusions. — 1. Is the path of soil water, etc., interfered with by girdling?

2. Can food material pass from the leaves, etc., back to the roots, when the stem is girdled? Reasons?

3. Is the path of the soil water therefore within the stem proper or in the inner layer of bark?

4. Is the path of the formed food (as sugar, etc.) therefore within the stem proper, or the inner layer of bark?

5. Explain Figure 24, writing a paragraph of description.

Fig. 24. — Diagram to show the regions in the stem through which the raw food materials pass up the stem, and food made in the leaf passes down the stem. (After Stevens.)

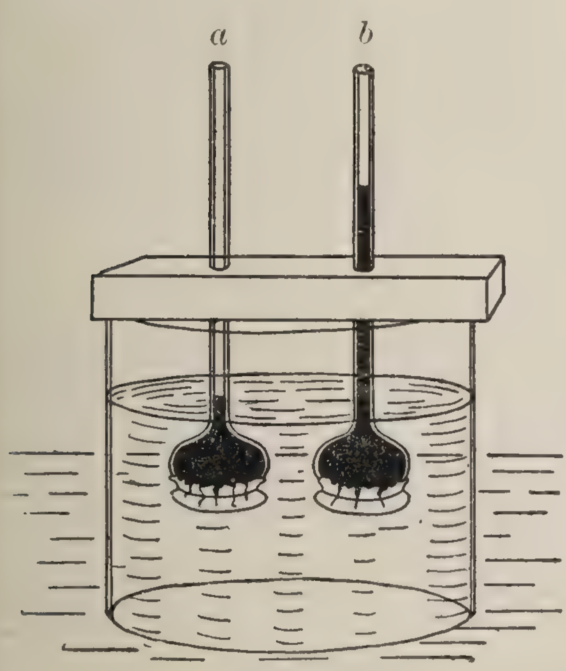

Fig. 25. — Experiment showing the osmosis of sugar, and the non-osmosis of starch. *a*, tube with starch and water; *b*, tube with sugar and water.

e. Condition of Food passing through the Stem

Method. — Half fill a tube with starch and water, and another with glucose and water. Put both tubes in a vessel of water as indicated, with the water on a level with the liquids in the tubes. After a day or so, test the liquids in the vessels for starch and for sugar.

Observations. — 1. Which tube shows the greatest change in level?

2. Which test was successful, for the starch or for the sugar?

Conclusions. — 1. Which substance was able to pass through the membrane?

2. Which one of the two is already soluble?

3. How might you change (digest) insoluble starch to soluble sugar? (See experiment, digestion in the corn grain, Prob. X.)

4. In what *form* must insoluble starch pass back and forth through the stem, and from cell to cell through cell walls?

f. How Stems protect Themselves (Optional)

Prickles, Spines, Thorns, Etc.	Bitter and Poisonous Substances	Flinty, Etc.	Hugging the Ground

Fill in the above table with as many plants as you can find that protect themselves as indicated at the top of the columns. Write a paragraph, summing up the information tabulated.

Questions

1. What are the uses to the plant of each of the parts shown in a cross section of a woody stem?

2. Where is the upward and downward path of liquids through a woody stem? Of a pithy stem?

3. What is the condition of food as it passes through the stem?

4. Mention some special uses to man of stems.

5. What is meant by grafting? Budding?

6. What are some of the methods of cutting timber?

7. What is the function of fibrovascular bundles?

Special Reports

1. Some methods of keeping forests.
2. Some methods of cutting timber.
3. Circulation through stems.

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Problem XVIII

A study of leaves in relation to their environment.

a. Reactions of Stems and Leaves to Light

Observations. — 1. Place some plants near a light window. Observe them for a few days.

2. Place a potted plant in a dark place for a number of days. Observe as above.

Conclusions. — 1. What conclusions can you make with reference to the effect of light on leaves and stems?

2. Why are leaves spread out so as to fill in all intervening spaces (*mosaics*)?

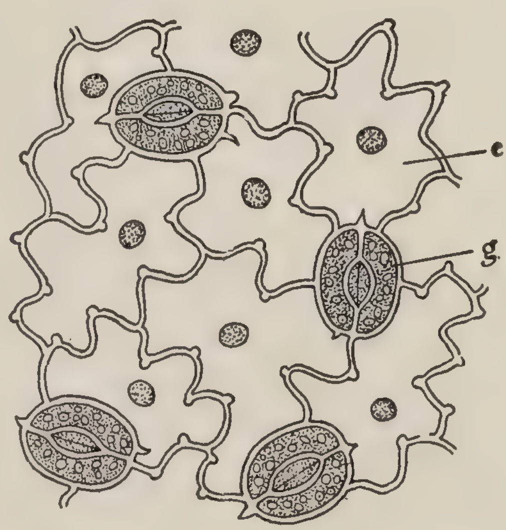

FIG. 26. — Stomata of epidermis of lower surface of a leaf. *e*, epidermal cell; *g*, guard cell of stomatic opening. (Tschirch.)

b. Structure

1. Stomata

Observations. — 1. Strip off a bit of the under surface of a leaf such as the onion, geranium, lily, or tradescantia, and examine with the low power of a portable microscope. Find numbers of small oval structures (*stomata*).

2. Find two oval or kidney-shaped cells (*guard cells*). These control the size of the opening into the leaf.

3. Examine a cross section of a leaf cut through some of the stomata. Do they open into the air spaces?

4. Do you find stomata on the upper surface of the leaf?

Conclusions. — 1. What seems to be the use of the stomata?

2. What might happen if they were plugged up with soot or dirt?

3. What advantage in their being on the under side of the leaf?

2. Inner Structure

Observations. — 1. Study the cross section of a leaf. Notice the epidermis of the upper surface appears as a nearly colorless row of cells. Are there any holes passing through it?

2. Just below the epidermis find long cylindrical cells (*palisade cells*). Do they contain small granules of green matter (*chlorophyll*)?

3. Under these find a spongy tissue of loosely joined cells (*parenchyma*) with air spaces between them. Do they contain as much chlorophyll as the palisade cells?

Conclusions. — 1. What is the meaning of the word "chlorophyll"?

2. Where do the openings of the stomata lead?

c. Important Functions

1. Absorption and Respiration

Observations. — 1. Make a tube of cardboard or thick paper about 1 inch in diameter and 10 inches long. Place a leaf over one end, hold the tube towards the sunlight, and look through it. How many leaves are necessary to absorb all the light?

2. What besides oxygen and nitrogen might pass into the leaf from the air?

Note. — Carbon dioxide is often called the "air food" of plants, as distinguished from its "soil food" or water and substances dissolved in it. These two raw food materials meet in

the leaf, and there unite to form elaborated foods, as starch, sugar, proteids, and oils.

Conclusions. — 1. If leaves absorb sunlight, they may therefore absorb energy. This energy is probably absorbed by the chlorophyll and is used in forming elaborated foods from soil

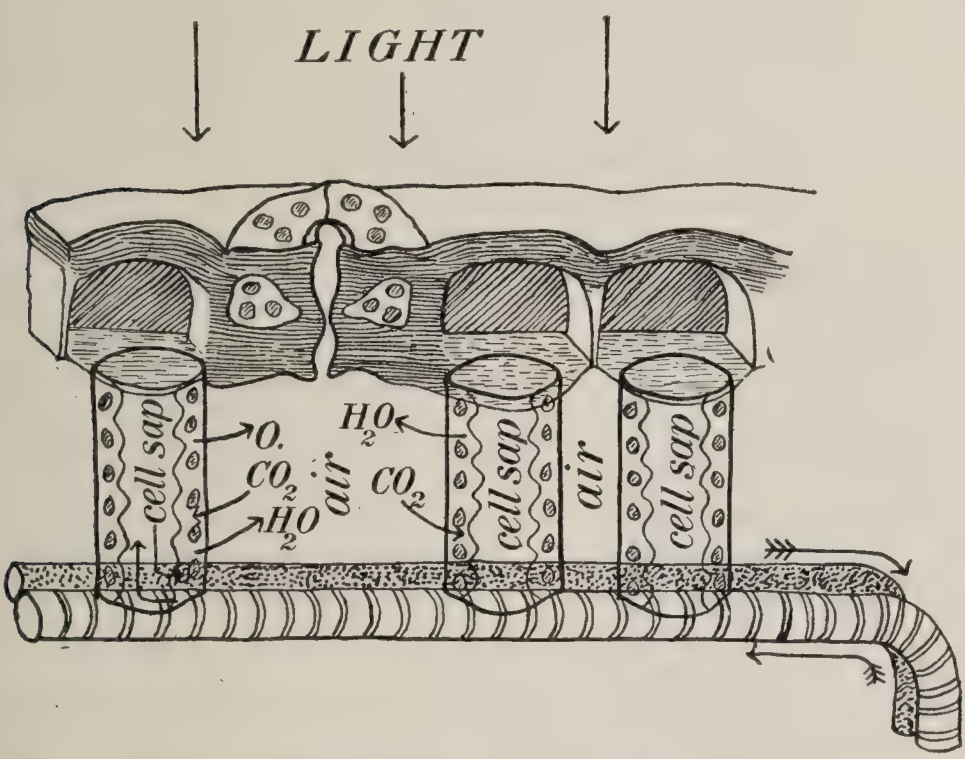

Fig. 27. — Diagram showing the essential working parts of a leaf. Note the stoma and the two tubes, one of which brings raw materials to the leaf, the other for removing the manufactured materials from the leaf.

and air foods spoken of above. Where is most of the chlorophyll located? Then where are most of the plant foods elaborated or built up?

2. Write a paragraph of description, telling all that is shown in Figure 27.

Observation. — Put a small plant, as a geranium, in a dark room for several days, so that the starch present in the leaves may be exhausted. Remove the plant from the dark room, and cover the lower surfaces of a few leaves with vaseline. Expose the plant to direct sunlight for a few hours. Pick off the leaves with the vaseline, also some without it, and dissolve out the chlorophyll with wood alcohol. Then place

them in iodine solution. Which leaves show the presence of starch?

Conclusions. — 1. What else besides sunlight, carbon dioxide, and water is a necessity to a leaf for starch formation?

2. If the leaf is alive and is doing work (making starch), what element is needed to release energy for doing the work? How does this element get into the leaf? (Respiration.)

2. Food Making and its By-products (Photosynthesis)

(*a*) *Starch Making* (*Important*)

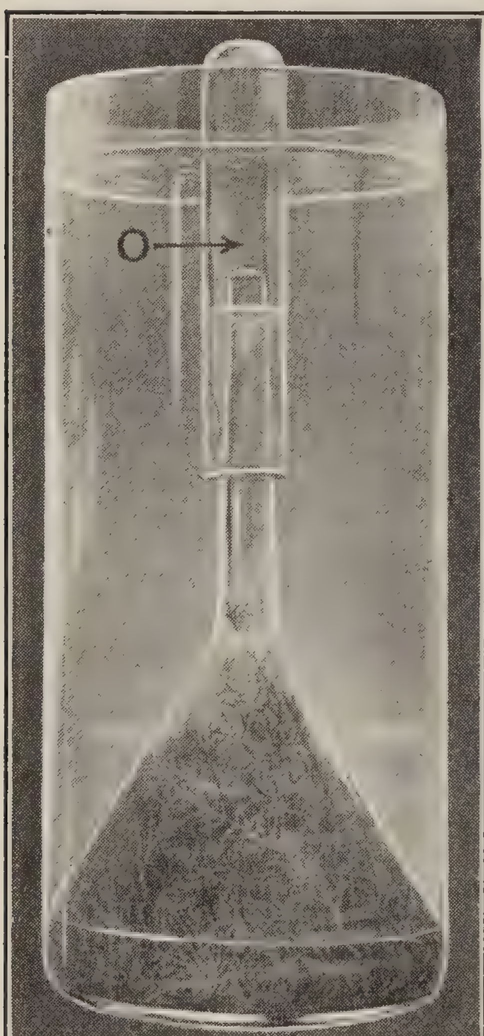

Fig. 28. — Experiment to show that oxygen is given off by green plants in sunlight.

Observations. — 1. Place some green water plants under a funnel in clear water as in Figure 28. *Note.* — Bubble carbon dioxide through the water (*not* under the funnel) several times in the course of the experiment. — Cork the end of the funnel, or invert a test tube filled with water over its neck. In either case see that the funnel tube is filled with water. Place the jar in sunlight for several days, and collect any escaping gas, either in the funnel tube, or in the test tube. Thrust a glowing splint into the gas. Result?

2. Set the apparatus as before, and let it stand overnight, or where the light cannot strike it. Has any gas been formed?

3. (*Optional.*) Immerse a sprig of geranium in water under a corked funnel, and set the jar in sunlight. Are bubbles given off? Place some mold, or toadstools, or other fungi under another funnel. Observe as before.

Conclusions. 1. What gas is given off by green plants in sunlight?

2. What gas have we learned is used as a food by green plants when they are in sunlight?

3. What substances have we learned are manufactured in the leaves?

Note.—The process of starch formation in green leaves by aid of sunlight and chlorophyll is known as *photosynthesis* (photo — light, and synthesis — a putting together).

This process may be chemically expressed somewhat as follows: energy (sunlight) + chlorophyll (assistant) + 6 CO_2 (carbon dioxide) + 5 H_2O (water) + ? H_2O = $C_6H_{10}O_5$ (starch) + energy (stored up) + 12 O (oxygen set free) + ? H_2O (water set free or *transpired*). This makes no pretense of being an exact equation, as the processes of photosynthesis are not fully understood.

4. Does photosynthesis take place in fungi?

(1) Starch (Analysis and Synthesis) (Optional)

Observations. — 1. Put starch in a test tube and heat it. Conduct any escaping gases by means of a bent glass or rubber tube to a small bottle of limewater. What change in the color of the starch?

2. What collects on the sides of the tube? Where must it have come from?

3. What change in the color of the limewater? What gas given off?

Note. — The separation of a substance into its parts is known as *analysis*, while the putting together of its parts is known as *synthesis*.

Conclusions. — 1. Which process took place in the test tube? In the leaf?

2. What two substances are found in starch?

(2) What Becomes of this Food?

Observation. — Select some healthy leaves growing in sunlight that test shows contain starch. Pin circular disks of cork on opposite sides of the leaf and after 24 hours test again for starch. Results?

Note. — Be sure to remove all the chlorophyll by changing the alcohol as many times as necessary.

Conclusions. — 1. Does starch remain where it is manufactured?

2. What has caused it to apparently disappear?

3. What has become of it? (See Prob. XVII.) (Condition of food as it passes through the stem.)

3. Evaporation of Excess Water (Transpiration)

Method a. — Cover a flower pot in which a vigorous leafy plant (a rubber plant or geranium, for example) is growing, with a rubber cloth so that only stems and leaves are exposed as in Figure 29. Water the plant well before fastening the cloth. (*a*) Place the pot under a bell jar; or (*b*) place it in a sunny place on a balance, and note the position of the pans from time to time.

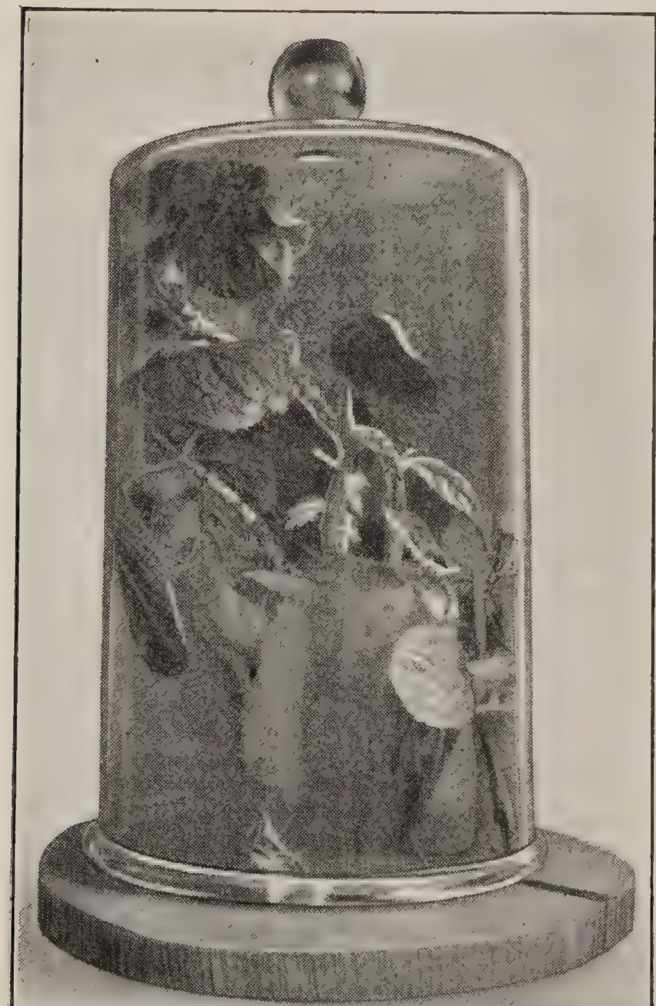

Fig. 29. — Experiment to show transpiration. Note the roots covered with root hairs growing from the main stem of the plant. Explain their origin.

Observations. — 1. What collects on the inner surface of the jar?

2. What is the loss of weight of the plant?

Conclusion. — Write the conclusion that fits the observation made.

Note. — The giving off through the leaves of the excess water of photosynthesis is called *transpiration.*

Observation. — Remove two large leaves from a plant, such as a rubber plant. See that they are of about the same size and weight. Cover the upper surface of one and the lower surface of the other

with vaseline. Also be sure to vaseline the petioles at the tips. Why? *Exactly* balance the leaves on the pans and put the scales in a sunny place.

Conclusions. — 1. Through which surface of a leaf does transpiration take place?

2. How do you arrive at your conclusions?

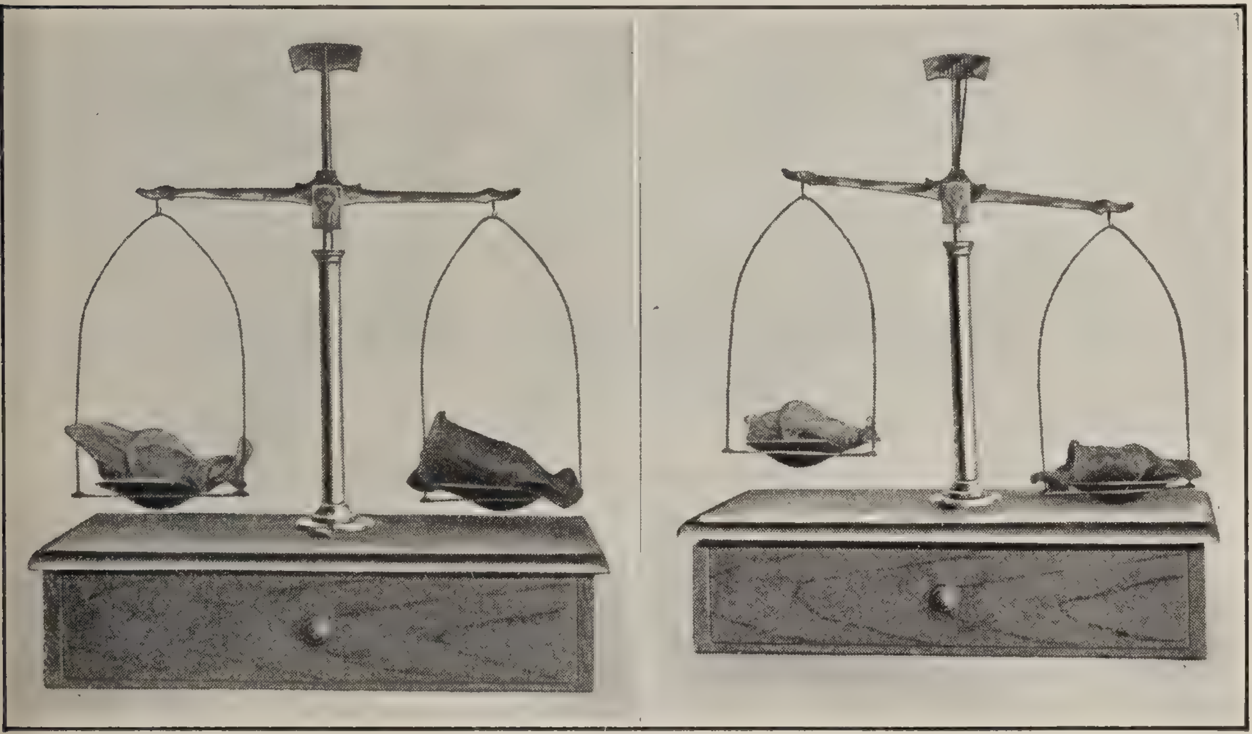

FIG. 30. — Experiment to show through which surface of a leaf transpiration takes place.

Method b. (*Optional.*) — 1. Insert a vigorous leafy branch in a cork borer to fit, that has previously been forced through a rubber stopper. Withdraw the borer, leaving the branch firmly fixed in the stopper. Press the stopper into the neck of a bottle of water. Set the bottle on a glass plate and cover it with a bell jar with vaselined rim so that it fits snugly. Place the apparatus in sunlight. Does moisture collect on the inner surface of the bell jar?

Note. — The experiment may be extended by weighing the stoppered bottle of water to see if there is any loss of weight. Is the loss of weight more rapid in sunlight or otherwise?

Conclusions. — 1. What condition favors rate of transpiration, or getting rid of excess water from leaves?

2. What happens when a plant wilts?

3. Why are plants kept fresh by placing them in water?

4. If evaporation of water is a cooling process, what is the effect produced on the climate by a large number of leafy trees?

5. Where would there likely be the most rainfall, — over forest areas or over areas where there are no trees? Explain.

6. Give an argument for the preservation of our forests.

7. Trace the ow of water in a plant from its absorption by osmosis in the root hairs, until it is either used in photosynthesis or transpired.

4. The Leaf as a Mill (Optional)

Conclusions. — 1. If the sun furnishes the energy to run the mill and the chlorophyll grains are the millstones, and the leaf the mill, and "air food" (carbon dioxide) and the "soil food" (soil water) are the raw products put into the mill, what is the manufactured product? The by-products?

2. Refer to Figure 27 and see if you can explain just where all the substances mentioned come from, and what becomes of them.

3. What are represented by the two lower tubes? Where does the incoming tube originate and what does it bring? What does the outgoing tube take away? In what condition, or what substance is it?

4. Just where have you already found these tubes located in the stem?

5. Try comparing the business of a leaf with the business of a factory, using such terms as "machinery," "raw materials," "manufactured products," "by-products," "wastes," "market," "transportation to market," etc.

d. Means of Protection (Optional)

1. Against Animals

Hairs	Prickles, Spines, Etc.	Bitter or Poisonous	Flinty	Hugging the Ground

Fill in the above table with as many plants as you can that have leaves that protect themselves as indicated at the tops of the columns. Write a paragraph, summing up the information tabulated.

2. Against Changes in Temperature

Rolling or Folding	Hairy	Resins, Gums, Wax, Etc.	Position of Stomata	Fleshy	Sleep of Leaves	No Leaves	Vertical Position

Tabulate in the above table examples of leaves that protect themselves as indicated at the heads of the columns. Sum up in a paragraph the information thus tabulated.

e. Some Leaf Modifications (Optional)

Spines	Tendrils	Food Storage	Water Storage	Insect Traps	Others

Fill in the above table with as many examples as you can, as a piece of home work.

f. Importance to Man

1	2	3	4	5	6	
Shade	Food	Loam	Water Supply (See Forestry)	Photosynthesis	Aquaria	Others

Tell just *how* leaves are of value to man under topics 4, 5, and 6. Tell *what* leaves are of value in the remaining columns.

g. (Optional.) A Study of the Ways Leaves and Stems, etc., protect themselves or Ways in which Plants adapt themselves so as to make a Greater Success of Life

1. *Begonia Leaf.* — Note the thickness of its epidermis. In what way is this a protection?

2. *Cactus.* — What are the leaves of the cactus? In what way do they protect the plant? What part does the work of leaves?

How does the absence of foliage leaves protect the cactus in its native surroundings?

3. *Cabbage Leaf.* — *Note* the waxy surface. How is this a protection?

4. Do leaves fall from trees in hot, dry weather? How is this of advantage? Do twigs drop from trees in the autumn? If so, is this any advantage?

5. Of what advantage is it that corn leaves and those of other plants curl on a hot day?

6. Examine a section of an India rubber leaf and note the position of the stomata. Is their position of any advantage? Explain.

7. Note the position of oxalis, or white clover, or squash seedlings, by day or by night. What difference of position? How are these positions a protection to the plant?

8. Examine leaves and stem of mullein. What do you find? Could these hairs protect against insect bites? Against extremes of temperature?

9. How do the following plants protect themselves partially from the attacks of animals (including man) — knotgrass, cut-grass, tomato, onion, ragweed, wormwood, bulb of Jack in pulpit, red peppers, mustard, horse-radish?

10. Examine the following plants and tell how they protect themselves, — thorn apple, barberry, locust, rosebush.

11. How may spines be especially helpful in regions to which cacti are peculiar?

12. Fill in the following summary:

Enemies of Plants	How Plants protect themselves from their Enemies

Questions

1. How prove that oxygen is liberated in photosynthesis? (Important.)

2. Why are the leaves spread out so as to fill in all the intervening spaces? (*mosaics.*)

3. The leaves of water plants may differ much in form, depending on whether they are above or below water. Explain.

4. Where is photosynthesis performed in the cactus? Why?

5. Why are most seed leaves and foliage leaves so different?

6. What is the result of the decomposition of carbon dioxide in a leaf?

7. Can starch be formed in darkness? Explain.

8. Pin the two halves of a cork on the opposite sides of a growing leaf exposed to sunshine. After a day or so dissolve out the chlorophyll, and test with iodine. Explain results.

9. Can mushrooms manufacture starch? Explain.

10. Where is all the starch in the world made?

11. Where and how does a plant get its water? Carbon? Oxygen? Hydrogen? Iron? Phosphorus? Nitrogen?

12. If cornstalks are burned on the ground, is there as much plant food returned to the soil as when they are plowed under?

13. Why does earth whiten celery when banked about it?

14. Why do plants near houses often become sickly, and sometimes die?

15. If leaves turn yellow and drop off after spraying with oily liquids for killing insects, what has probably happened? (Remember the functions of the stomata.)

16. If the stomata of plants are mostly closed at night, when would be the best time to fumigate or spray the plants? Reasons.

17. What great danger to plants in the neighborhood of factories, etc.? Are frequent rains a benefit? Explain.

18. Show why the leaves of house plants should receive an occasional washing with water.

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PROBLEM XIX (Optional)

Some uses of stems.

a. Special Products from Stems

1. Fill in the following table. (See Chap. X, Hunter, *Essentials of Biology*.)

Substance	Source
Food	
Lumber	
Cork	
Linen	
Wood Pulp	
Latex For Rubber . . .	
Resin	
Sugar Sap	
Hemp	
Turpentine	
Fuel	
Tannin	
Peruvian Bark (Quinine)	
Cassava	

2. Write a paragraph summing up the information shown.

b. Some Woods and their Value

1. Find out as many woods as you can that are of value because of the properties listed in the following table, and put in the proper column. (See Hunter, *Essentials of Biology*, Chap X.)

Resistance to Decay	Hardness and Strength	Softness	Beauty of Grain and Polish

2. Try to determine the kinds of wood that compose the wood trim of the room you are in. Notice the top of your desk, the floor boards, trim of the wainscoting, etc. Compare with the diagram, page 138, Hunter, *Essentials of Biology*, and determine how the wood was cut to get the grain you see.

How would you explain the marking of bird's-eye maple? (Study Figure of a knot, page 139, Hunter, *Essentials of Biology*.)

3. Which of the above woods are cheap? Expensive? Why, in each case?

c. Government Field Work in Forestry[1]

Form 416

Species------------------------------------

Period covered by observations------------------------------------

Name of observer------------------------------------

Residence------------------------------------

(State) (County) (Town)

General character of country. — *Mountains; foothills; plains; river valley; seacoast.*

Situation of trees. — *Level; slope (north, east, west, south); hilltop; river bottom; soil (sandy, clayey, heavy, light, deep, shallow, moist, dry).*

(Please check the words which apply to your particular locality and to the trees observed.)

Approximate elevation above sea level------------------------------------

Location of nearest Weather Bureau station------------------------------------

State if season was wet or dry, early or late, etc.------------------------------------

[1] From the U. S Forest Service, U. S. Department of Agriculture.

	Date		Date
1. *Swelling of buds*		8. *Beginning of leaf falling*	
2. *Bursting of buds*		9. *Ending of leaf falling*	
3. *Beginning of leafing out*		10. *Beginning of seed ripening*	
4. *General leafing out*		11. *General seed ripening*	
5. *Beginning of blossoming*		12. *Beginning of seed falling*	
6. *General blossoming*		13. *General seed falling*	

7. *Change in color of foliage* --

14. *Quantity of seed* ------------------------

15. *Quality of seed* ------------------------

General remarks --

Note. — Using the above model, make a study of a few trees. Send a copy to U. S. Department of Agriculture, Washington, D.C.

d. Tree Study Bulletin

1. Extent of root system.
2. General shape of tree.
3. Height of trunk compared with top.
4. Shape of leaves.
5. Where leaves borne on tree.
6. How leaves arranged on twig.
7. Form of seeds and how distributed.
8. Where and how seeds planted.
9. Study of ground shaded by tree, and plants growing there.
10. Name of tree.
11. Name of observer.
12. Date.

Use the above form and make a study of a few trees.

Questions

1. Name the purpose of plant stems.
2. What is the purpose of branching?
3. The cause of knots in lumber?
4. The purpose of pruning? How is it done?
5. The purpose of grafting? How is it done?

6. What is grafting wax? How is it made?
7. What is budding? How is it done?
8. Name some stems useful to man.
9. Name some stem products useful to man.
10. Name some twining stems. Some fleshy stems.
11. The uses of rattan and bamboo.
12. The storage of starch in stems.
13. The effect of girdling stems.
14. What is the cambium layer?
15. How may stems protect themselves?
16. Why are the forests and streams of Maine of more worth than her agricultural resources?
17. Why should Victor Hugo say, "For the world lets everything perish which is nothing but selfishness — everything that does not represent an idea or a benefit for the human race"?

Special Reports

1. History and origin of the potato.
2. Commercial products from stems.
3. The big trees of California.
4. Methods of forest preservation.
5. The manufacture of paper from stems.
6. Stems used as food.
7. Government field work in forestry.
8. Plant propagation by stems.

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PROBLEM XX (Optional)

Some forms of plant life with special reference to nutrition and reproduction.

a. An Alga

Pond Scum (Spirogyra)

1. General

Method. — Mount some of the material in water and study with low power of a microscope.

Observations. — 1. What is the shape of a single plant? *Note.* — A threadlike body is called a *filament.*

2. Is it one-celled or many-celled?

3. Can you find any roots or leaves?

4. What is the color? What are plants that contain chlorophyll able to manufacture?

Conclusions. — 1. Would you consider this plant to be simple or complex?

2. Show if any part corresponds in function to leaves.

2. Reproduction

(a) Sexual

Observations. — 1. Find filaments joined so as to form ladder-like structures. Here cells send out tubes which connect with similar tubes

from the neighboring cells of another filament, so that the contents of one cell may pass over and mix with the contents of another. This is a *sexual* method of reproduction. The part passing over is said to be the *supplying* or *male gamete*, while the part to which it fuses is called the *receiving* or *female gamete*.

2. Can you find any cells emptied of their contents? If so, what do you find in the neighboring cell? *Note.* — The result of *conjugation* or the union of the male and female gametes is to form a new cell, called a *spore* (zygospore, or yoke spore). The receiving *gamete* is said to be *fertilized*.

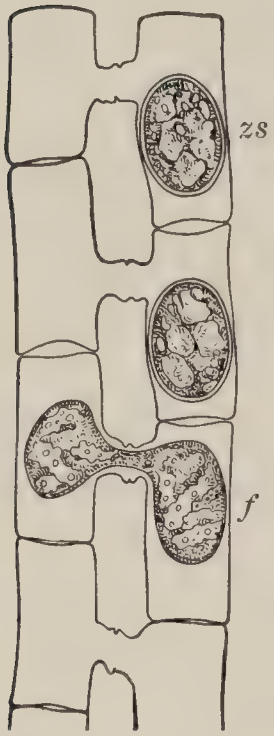

Fig. 31. — Conjugation of Spirogyra. *f*, fusion in progress; *zs*, zygospore.

3. Can you find any such spores? If so, do they have thin or thick walls about them?

Note. — These spores are also said to be "resting spores" and correspond to seeds. The outer coat enables them to resist freezing, drying, etc. Like seeds, they sprout whenever the conditions are favorable.

Conclusions. — 1. Explain how these plants survive the drying up of ponds in summer, or the cold of winter.

2. Write a paragraph on the sexual method of reproduction in Spirogyra.

3. Write another paragraph on the advantages of the sexual method of reproduction in Spirogyra.

(*b*) *Asexual*

Note. — The filaments of these plants break into parts at certain times, and these parts form new plants. This method of producing new plants is called *asexual reproduction.*

b. A Fungus

Materials. — Ordinary mold on decaying fruits and vegetables, or on bread.

Observations. — 1. What is the color of the mold?

2. Does it contain chlorophyll?

Conclusion. — Can this plant manufacture its own food?

Note. — Plants unable to manufacture their own food are much like animals in that respect. If they live directly on living plants or animals they are said to be *parasites*, while if they obtain their food from dead bodies or organic wastes, as the molds do, then they are said to be *saprophytes.*

Observations. — 1. Find tiny bodies on stalks (spore cases or *sporangia*). (Use low power of microscope.)

2. Some of these sporangia may be broken open by pressing on the cover glass. Can you find small spherical bodies (*spores*) therein?

Conclusions. — 1. What method of reproduction is here represented, the asexual (vegetative), or the sexual? Explain.

2. Do you judge these spores were formed by *cell union* or *cell division?* Explain.

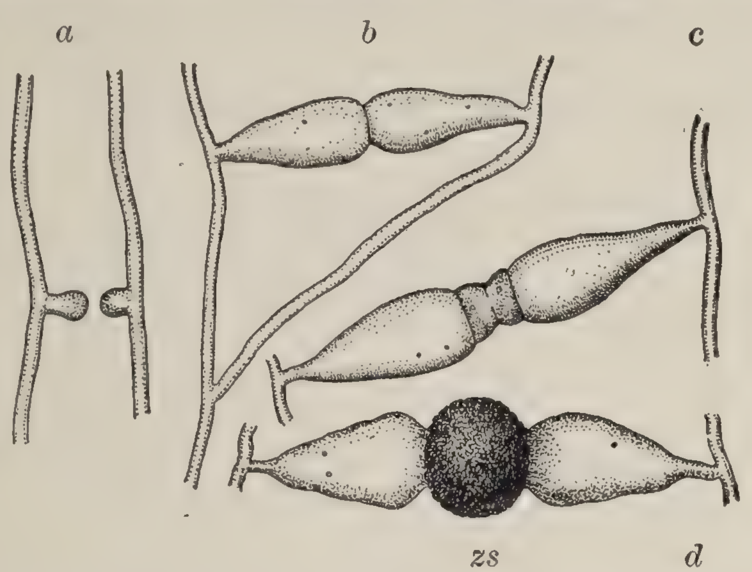

FIG. 32. — Conjugation of mold. *a*, *b*, *c*, *d*, successive stages in the formation of the zygospore, *zs*.

Observations. — 1. (Dem.) Search deep in the mold for large dark bodies (*zygospores*), formed where the tubes from mold filaments meet.

2. Study Figure 32. What resemblance shown to reproduction in Spirogyra?

Conclusions. — 1. What method of reproduction is here illustrated?

2. What must evidently be the purpose of the zygospores here? (See Spirogyra.)

c. A Moss

Observations. — 1. Examine specimens of any kind of moss — preferably pigeon wheat moss. Do you find root, stem, and leaves?

2. Is there chlorophyll present?

Conclusion. — Is this plant able to manufacture its own food (independent) or does it use food already made (dependent)?

Observations. — 1. Find tiny capsules at the tips of slender stalks. How are they covered?

2. Crush one on a slide and examine it with low power. What do the capsules contain?

Conclusion. — What method of reproduction is here evidently shown? *Note.* — The capsule is on a stalk, which is rooted in the tip of the leafy plant. It is in reality a separate plant, but with no leaves of its own. Where, then, must it get its food? Is it a parasite?

Observation. — Refer to charts, models, or slides. What results from the sprouting of a moss spore? *Note.* — The asexual spore grows

into a threadlike plant, which finally develops into a leafy moss plant. This produces sex organs at its tip, which correspond to the anthers and pistils of an ordinary flower. An anther-like organ is called an *antheridium* and produces male cells called *antherozoids*, corresponding to pollen. These are able to swim (*motile*) in water, however. A pistil-like organ (*archegonium*) contains a single, comparatively large female cell, called an *egg*.

Conclusions. — 1. By what means must the male cell reach the egg?

2. What method of generation is here illustrated? Explain.

3. When an asexual generation is followed by a sexual one, it is called *alternation of generations*. Show how it is illustrated here.

d. A Fern

Observations. — 1. Observe a common fern plant. Are there root, stem, and leaf?

2. What is the color?

Conclusion. — Could this plant be called a parasite? A saprophyte? Explain.

Observations. — 1. Look on the under side of the leaves for small fruit dots, or spore cases. How are they distributed?

Note. — Plants producing asexual spores are called spore plants, or *sporophytes*. Those producing sexual spores (*gametes*) are known as *gametophytes*.

2. Crush a spore case on a slide and examine it with low power. (A good figure or chart may suffice.) What is the form of the spores?

Conclusion. — What method of reproduction is here shown? Explain.

Observations. — 1. Refer to a good figure or chart, and find what develops from the growth of an asexual spore. Does it have roots?

2. Find organs corresponding to anthers and pistils on the small plant (*prothallus*) which grows from the spore. Just where are they located? *Note.*—The antheridia and archegonia are here much as in the moss. The male cells are able to swim in rain or dew, so that they may reach the egg.

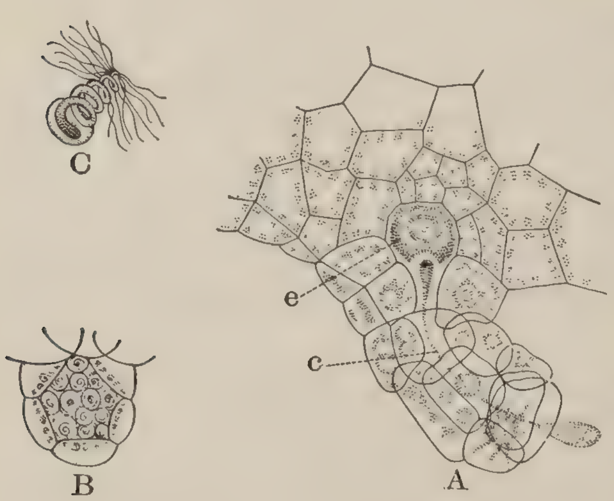

Fig. 33. — *A*, Archegonium of fern; *c*, canal; *e*, egg. *B*, antheridium, which produces male fertilizing cells; *C*, antherozoid or male fertilizing cell, highly magnified. (After Strasburger.)

Conclusions. — 1. What generation does the prothallus represent? Explain.

2. Show how there is alternation of generations.

Observations. — 1. Study Figure 33. Just where is the egg cell located?

2. Just how must the antherozoid or sperm cell (C) reach the egg cell (e)?

Conclusions. — 1. Does the process of fertilization here take place internally or externally? Explain.

2. Show if it is of any advantage to an egg cell that it be reached only through a small tube.

3. Could the egg cell be fertilized if the archegonial tube was perfectly dry? Explain.

4. Fill in the following summary:

Plants	Ways Sperm Cells reach the Egg	Sketches
Spirogyra		
Mold		
Moss		
Fern		
Tulip		

Questions

1. Explain the term 'alternation of generations.'
2. What advantages result from alternation of generations?
3. Are ferns independent or dependent plants? Explain.
4. Which method of reproduction better enables a plant to fight adverse conditions? Which for rapid and easy multiplication?
5. What disadvantages to a moss plant that the sporophyte be dependent on the leafy plant (gametophyte)? What advantages?
6. What conditions favor the growth of molds?
7. What is meant by vegetative or asexual reproduction? By sexual reproduction?
8. What is a sporophyte? Give an example. A gametophyte? Example?
9. What are parasitic plants? Example? Saprophytic? Example?
10. What is the essential process of fertilization?
11. Why must male germ cells be so much more abundant than eggs?
12. Why must plants and animals reproduce themselves?

13. Why are male fertilizing cells so much smaller than eggs?

Note. — Water plants set sperm and eggs free in the water, where fertilization takes place and the resulting spore (seed) usually sinks to the bottom to germinate when conditions are right.

14. Why must mosses, ferns, etc., protect their eggs until and *after* fertilization? How is this accomplished?

Special Reports

1. The advantages and disadvantages of alternation of generations.
2. Means of overcoming unfavorable conditions of development.
3. The importance of protecting the egg.
4. Ways in which sperm cells reach the egg.
5. The main differences between algæ and fungi.

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PROBLEM XXI (Optional)

A study of the way plants are modified by their surroundings. (A field trip.)

INTRODUCTION

Note. — Most plants must have soil, water, light, air, and proper temperature in order to grow. Plants use these factors in different proportions, so are organized into *groups* or *societies*, which express their relations to these different factors. As the relation or reaction to water is perhaps as evident and universal as any, it is commonly used as the basis of grouping. Thus there are: —

a. Hydrophytes, or water plants, or groups.

b. Xerophytes, or those in sandy, rocky, or other dry places.

c. Mesophytes, or those intermediate between water plants and those of dry regions.

Other divisions may be also made on a temperature or on a soil basis. The above societies may be further subdivided into swamp society, pond society, rock society, sand society, meadow society, thicket society, prairie society, forest society, etc., or they may take their names from the most conspicuous plant present, as an oak, cactus, or water lily society.

a. Hydrophyte Society

Observations. — 1. Select any region where there is a pond, marsh, or running water, and plenty of water plants. Find out the names of the plants, if you can; if not, give any common names, or describe them as best you can. Are there few or many plants?

Fig. 34. — Photograph of plant societies. Note the different zones of vegetation.

2. Are there any plants entirely submerged? Any floating? Do any rise in the air?

3. What differences between submerged leaves and those exposed to the air?

4. How do the roots of plants entirely free from the soil differ from ordinary roots?

Conclusions. — 1. Are submerged leaves affected by sun exposure? If not, do they need to be as entire and fleshy? Explain.

2. How must floating plants obtain their supply of soil substance?

3. What takes the place of leaves in the algalike plants?

Observations. — 1. Cut off the stems of some of the larger water plants, and note their interior structure. How would you describe it?

2. Look for stomata with a hand lens, — or after returning from your

trip. Look especially on the leaves of such plants as the water lily. Are they on the upper or lower side of the leaves?

Conclusions. — 1. Is a stem of spongy tissue well or poorly adapted to permit air from the water to reach its interior?

2. What advantage in the stomata being on the upper side of a leaf?

Observation. — Pull up one of the rooted plants. How do they differ from any near-by land plant? How do the roots of each differ?

Conclusion. — What seem to be the main functions of the roots of such water plants?

b. Xerophyte Society

Observations. — (Study such plants as the cactus, rubber plant, and century plant. If none are growing wild, visit greenhouses.)

1. What is the character of the soil, — sand, rock, or clay, etc.?

2. Find water content as under mesophytes (meadow).

3. What plants do you find? Which are the most abundant?

4. Pull up some of the plants and examine the roots, if growing wild. How do they compare with those of mesophytes? Hydrophytes?

Conclusion. — Why do these plants need long roots?

Observations. — 1. Do all of these plants have leaves? If so, how do they compare in thickness and width with mesophytic plants? Hydrophytic?

Conclusions. — 1. Why should xerophytic plants either be leafless, or with leaves usually thick and fleshy?

2. If no leaves are present, what is the character of the stem?

c. Mesophyte Society

1. Meadow

Observations. — 1. Collect a sample of the soil in a pint fruit jar. Bring it to the laboratory and get the weight of the sample. Then dry the sample thoroughly, using slow heat. What is the weight of the soil water in your sample? What is the percentage of water (water content) in the meadow soil?

2. Get the names of all the plants growing here that you can. Are they few or abundant?

3. Pull up a few of the plants and note their roots. How do they differ from those of the hydrophytes? Do you find root hairs?

Conclusions. — 1. Can you think of any reason why the roots of meadow mesophytes should be better developed than those of hydrophytes?

2. Do you think the water content of the soil is such as to satisfy a hydrophyte?

Observation. — Cut off the stems of some of these plants. Is their structure more or less spongy than hydrophytes?

Conclusion. — Are the stems of meadow mesophytes more or less able to serve as supporting organs as compared with the stems of hydrophytes?

Observations. — 1. Note the number of leaves. Are they more or less abundant than with hydrophytes?

2. Note the fleshiness, thickness, and breadth of the leaves. How do they compare with hydrophytes?

Conclusion. — Show whether the leaves of hydrophytes would be well or poorly adapted to carry on the work required of them by meadow mesophytes. (Refer to pages 102–103: Means of protection against enemies, climate, etc.)

Observation. — Look for stomata. On which side of the leaf do you find them?

Conclusions. — 1. How do the locations of stomata in these plants compare with those of hydrophytes? Any reason for different locations?

2. Do you think the plants you have studied are *perfectly* adapted to their habitat? Give reasons. *Note.* — If plants are not well adapted to their environment, they will be stunted in growth, reproduce themselves poorly, and be easily killed or driven out.

3. Do you think any of these plants could live about as readily in any other habitat as in a hydrophytic or xerophytic region? That is, are plants always killed out if they do not readily find their special habitat?

May such a plant as a willow flourish as a hydrophyte if such a habitat should accidentally be thrust upon it?

2. Forest

1. Thickets.
2. Deciduous forests.
3. Evergreen forests.

Method. — Follow the same method of procedure as for meadow.

3. Sandy Plain or Sandy Roadside

Method. — As for meadow.

d. Summary

Observations. — 1. Fill in the following tabulation, as far as possible:

Plant Societies	Character of Land	Some Typical Plants	Character of Stem	Character of Leaves	Character of Roots	Relation to Man
Xerophytes . . .						
Mesophytes (*a*) Meadow . (*b*) Forest . . (*c*) Sandy plain						
Hydrophytes . .						

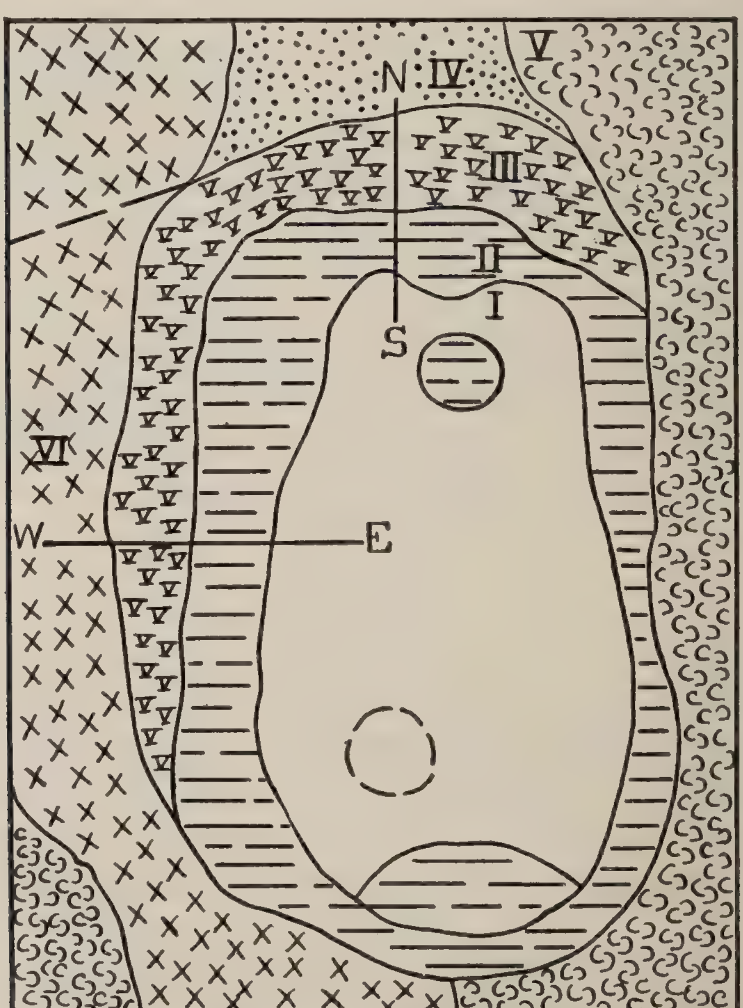

FIG. 35.—Diagram of zonation about a pond. I, pond; II, bog zone; III swampy thicket zone; IV, incomplete zone in barren soil of a sand pit; V, dry meadow zone; VI, dry woodland zone. (After Bergen and Davis.)

e. Plant Zonation

Observations. — 1. Show how the distribution of plants depends largely on the character of the ground they occupy.

2. How do meadow and forest formations differ? Sea beach from swamp? Swamp from pond?

3. Study Figure 35. Note the subdivisions into zones. How many are there? How are they named?

Conclusion. — What factor has evidently caused most of the differences in the characters of the zones?

Observation. — Using Figure 35 as a model, make a study of any pond formation and try to make a similar diagram.

Conclusion. — Report your observations, including as many names of plants as possible, also differences in appearance between the zones, etc. Thus:

	Fleshy Plants	Rooted — Submerged	Rooted, but Part in Air	Plants mostly in Air	Plants All in Air

Questions

1. Show how plant societies depend on the variations in surroundings (physiographic conditions).

2. Which of the plant societies is most directly concerned with man's welfare?

3. Why were the valleys of the Euphrates and the Nile centers of early civilization?

4. What part of the United States is the most productive? Why?

5. Explain the advantages of irrigation in such states as Colorado, Utah, and Arizona.

6. What is meant by the "timber line"? Under what conditions does it exist?

7. Where are the conditions the more variable, in the arctics or tropics? Then where would there be more variation in plant life?

8. As ponds dry up, do different plant societies follow one another? Explain.

9. How does the arctic willow vary from its relative of the temperate zone? Why?

10. How do floating plants get their supply of soil substance?

11. Where are there xerophytic forests in the United States?

12. What are halophytes? What are their characteristics?

Special Reports

1. The factors that determine plant association.
2. How plants protect themselves from drought.
3. The effect of cold regions on plants.

References

Hunter, *Essentials of Biology*. Chap. XII.

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THE BIOLOGICAL INTERRELATIONS OF PLANTS AND ANIMALS

PROBLEM XXII

Some relations of fungi to man.

a. Conditions and Results of the Growth of Yeast

1. Food

Method. — Mix part of a cake of compressed yeast in a little water to form a thin paste.

Prepare five wide-mouthed bottles, labeling them 1 to 5. In No. 1 put some yeast and water.

In No. 2 put some yeast and some molasses or glucose. Set the two bottles aside in a moderately warm place and observe after 24 hours.

Observations. — 1. What is the smell and taste of No. 1?

2. What is the color in No. 1?

3. What are the smell, taste, and color of No. 2?

Conclusions. — 1. What evidence is there that the yeast is working in one of the bottles? Which one?

2. What is one of the conditions necessary for the growth of yeast?

2. Temperature

Observations. — 1. Pour some of the mixture from bottle No. 2 into bottles Nos. 3 and 4. Set No. 3 aside in a jar of cracked ice or in a refrigerator. Result in a few hours?

2. Set No. 4 in a jar of boiling water, and heat it to boiling. Set it aside to cool. Result?

Conclusion. — Name some conditions of temperature harmful to the growth of yeast.

3. Results of Growth

Observations. — 1. Loosely stopper a bottle containing growing yeast. Draw out some of the gas above the yeast by means of a large bulb pipette and bubble the gas through limewater. Result?

2. Show how, when yeast is put into dough, the conditions of its growth are present.

3. What gas must be set free in the dough?

4. What happens when yeast acts in sugar?

Note. — The name of this process is *fermentation.*

Conclusions. — 1. What causes bread to rise?

2. Why does bread "fall" if not baked soon after it has risen?

3. Why set the dough in a warm place for rising?

b. Some Economic Relations of Other Fungi

Observation. — Tabulate the information called for in the following table, so far as you are able:

Fungi

Names	How Useful	How Harmful
Yeast		
Molds		
Corn Smut		
Mushrooms		
Bracket Fungus		
Wheat Rust		
Potato Scab		

Questions

1. What becomes of the alcohol produced by using yeast in dough?

2. Explain the use of yeast in bread making.

3. Why use yeast in wine making? Beer making?
4. Are there yeast plants in the air? How can you prove it?

Special Reports

1. Bread making.
2. The brewing industry.
3. Some useful fungi.
4. Some harmful fungi.
5. The wheat rust.
6. The corn smut.
7. The chestnut fungus.

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Conn, *Bacteria, Yeast, and Molds in the Home.*

PROBLEM XXIII

A study of bacteria, and of some of their relations to man.

a. Conditions of Growth

Materials. — One pint of fresh milk, box of cracked ice. Nutrient gelatine in tubes as put up by Parke, Davis & Co. Some sterilized Petri dishes with covers. Some sterilized flasks and corks. (Sterilize them by boiling them in water for fifteen minutes.) Alcohol lamp or Bunsen burner.

Observations. — 1. Pour equal amounts of milk into each of 3 flasks. Label them 1, 2, and 3. Cork No. 1 and set it aside in a moderately warm room. Cork No. 2 and place it in an ice box or in cracked ice. Boil the milk in No. 3 for half an hour, plug the flask with sterilized cotton, and set it with flask No. 1. Are there any differences in smell and taste in the course of a few days?

2. Put some nutrient solution in each of three sterilized Petri dishes. Label them 1, 2, and 3. Expose No. 1 to the dusty air of a room for a few minutes. Cover it and set it aside in a shady warm place. Examine it after a day or so. Is there any noticeable effect on the gelatine?

3. Place No. 2 in direct sunlight as much as possible. (Keep it moderately cool.) Results as before?

4. Place No. 3 uncovered but in a very dry place for a few days. Results?

Conclusions. — 1. What effect have dark warm places on the growth of bacteria?

2. What effect has sunlight on the growth of bacteria? Lack of moisture?

3. What conditions favor the growth of bacteria?

4. What are some of the conditions that retard or hinder the growth of bacteria?

5. What causes food to spoil?

6. Name some of the various ways of preserving food. Explain just why they may be successful.

b. Some Relations to Man

1. Putrefaction or Decay

Materials. — Hay infusion, beef juice, microscope, slides, charts or figures of bacteria.

Observations. — 1. Make a hay infusion by pouring some hot water on some chopped-up hay in a quart jar, and allowing to stand a day or so in a warm place. What changes in color do you observe? *Note.* — There must have been some germs on the hay that developed as soon as it was warm and moist enough. These germs must have survived the hot water, and after it was the right temperature, developed rapidly, feeding on the infusion from the hay.

2. Prepare some beef juice and set it aside in a warm place, in a beaker. After a day or so note any changes in color and odor.

3. Examine a drop from each of the preparations with at least a $\frac{1}{6}$-inch objective, — use a higher power if possible. Do you see any signs of life? Compare them with Figure 36.

Conclusions. — 1. What do you think caused the hay and the beef juice to change their color and odor (decay or putrefy)?

2. What would happen if organic matter did not decay?

3. May these bacteria be useful or harmful to man?

2. Some Other Useful Bacteria

Observations. — 1. Set aside some cream in a moderately warm place for a day or so. Results? Odor and taste?

2. Squeeze some juice from apples. Set it aside as above. Results?

3. Set aside some fresh grape juice as above. Results?

4. Bruise an apple or banana. Set it aside in a moderate warm place for several days. Results?

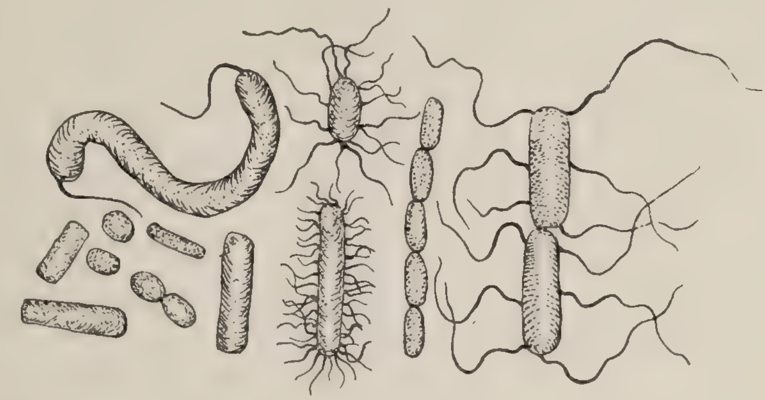

Fig. 36. — Useful bacteria which change dead matter into food for grass, wheat, and corn. Highly magnified.

5. Explain how linen fibers are prepared.

6. Which sort of cheese is considered the better, that freshly made or that aged? Explain.

7. What causes nodules to form on the roots of such plants as clover, alfalfa, bean, etc.? (See page 82.)

Conclusions. — 1. What is the benefit of ripening or souring cream? What has probably caused it to do so?

2. What is the result of the action of bacteria on the alcohol of fruit juices? *Note.* — The alcohol was formed by the action of yeast from the air or on the fruit, fermenting the sweet juices, resulting in cider, wine, etc. The alcohol is then attacked by bacteria, which change it into an acid (acetic acid).

3. What is meant by decay? *Note.* — An example of decay of starch might be represented as follows:

$$\textit{Decay} = \text{Starch} + \text{oxygen} = \text{carbon dioxide} + \text{water}$$
$$C_6H_{10}O_5 + 6\,O_2 \quad = \quad 6\,CO_2 + 5\,H_2O$$

The growth of the same starch may be represented as follows:

$$\textit{Growth} = \text{Carbon dioxide} + \text{water} = \text{starch} + \text{free oxygen}$$
$$6\,CO_2 + 5H_2O = C_6H_{10}O_5 + 6\,O_2$$

4. What is meant by 'fertilizing the soil'?

5. What would happen to the plant nourishment in the soil if there were no decaying organic matter to add to it?

6. Write a paragraph, telling how some bacteria may be useful to man.

7. Write another paragraph, showing that but for useful bacteria the world would be a desert, and man himself could not exist.

c. Some Methods of Fighting Harmful Bacteria

1. Disinfection or Sterilization

Materials. — Nutrient gelatine or agar-agar, milk, 5% carbolic acid, 4% formalin, and lysol if possible. Steam or hot air sterilizer. Ice box or cracked ice.

Observations. — 1. Inoculate each of six tubes of gelatine with bacteria by touching colonies of bacterial growth with a sterilized platinum wire or a needle, and transferring to the gelatine. Cork each one with sterilized cotton. Label the tubes 1 to 6. Place No. 1 in a warm place. What is the result in three days? Five days?

2. Cover the surface of No. 2 with carbolic acid solution, seal, and set it in a warm place. What are the results in three days? Five days?

3. Cover the surface of No. 3 with 4% formalin and set it in a warm place. What are the results in three days? Five days?

4. Cover the surface of No. 4 with corrosive sublimate solution. What are the results in three days? Five days?

5. Cover No. 5 with 70% alcohol, and set it in a warm place. What are the results in three days? Five days?

6. Sterilize No. 6 in the sterilizer for one half hour. Seal at

once and set it in a warm place. Observe the results in three days. Five days.

7. Seal No. 7 and place it in an ice box or in cracked ice. Observe the results in three days. Five days.

8. Tabulate your results as follows:

	1. Normal Growth	2. Carbolic Acid	3. Formalin	4. Corros. Sub.	5. Alcohol	6. High Temp.	7. Low Temp.	8. Extra Notes
Appearance in 3 days								
Appearance in 5 days								

Conclusions. — 1. Which of the above methods of disinfection do you think is the best? Why?

2. Why is it necessary to heat foods before canning them?
3. Why is hay dried before it is put into the barn?
4. Why put foods in the refrigerator in the summer time?
5. What conditions hinder the growth of bacteria?

2. Pasteurization

Note. — Pasteurization is the heating of a substance to about 160° F. long enough to kill most of the germs.

Materials. — One pint of milk, two sterilized fruit or agate jars, thermometer, alcohol lamp or Bunsen burner, double cooker or hot air sterilizer.

Note. — Special pasteurization apparatus as shown in Figure 37 may be procured for a small sum.

Observations. — 1. Put a half pint of milk in one of the sterilized fruit jars, and set it uncovered in a warm place. Result after two days? Taste, odor, etc.?

2. Place a half pint of milk in another of the sterilized jars (or it may be placed in the inner vessel of a double cooker that

has been sterilized). Set it in a vessel of boiling water just removed from the flame, and heat it to 150–160° F. or 66–72° C., stirring with a clean spoon for 10 minutes. Let it remain for 15 minutes, then *quickly* cool. Set it aside with the other jar, and compare them after a day or so. Result? Taste, odor, etc.? Which is the sweeter tasting? Which has the sweeter odor? Which is therefore purer, or freer of germs?

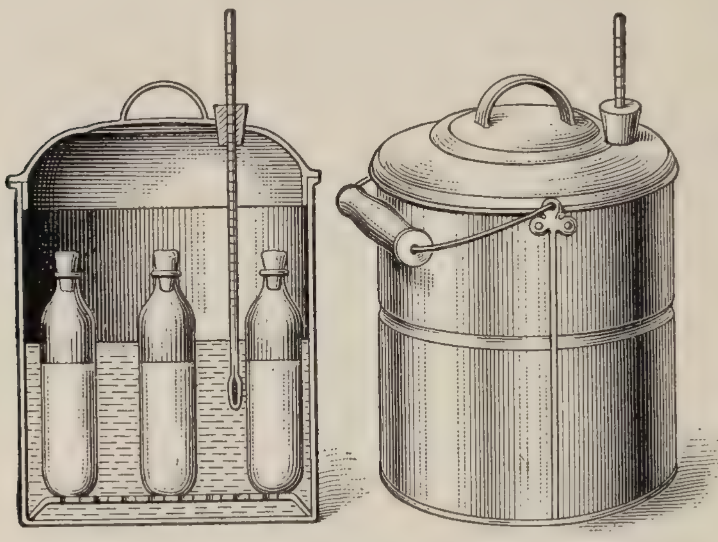

Fig. 37. — Pasteurizing apparatus.

Note. — *Discontinuous* sterilization or pasteurization may be performed by heating the substance to be sterilized twice a day just as for ordinary sterilization. Continue thus for two or three days. Why?

Conclusions. — 1. How may milk be pasteurized?

2. What is the benefit of pasteurization?

3. Why should milk be marketed in bottles?

Observations. — 1. Carefully pour the milk from the pail or bottle at home, after it has stood several hours, and see if there is any sediment left. Result?

2. Taste the milk used at home. Does it leave a slightly unpleasant taste, reminding one of the odor about cow barns? If so, the milk should be pasteurized before using.

Note. — Boiling may do, but it renders it somewhat more difficult of digestion and also changes the taste, so that it is especially distasteful to some; therefore pasteurization is to be preferred.

Conclusions. — 1. What do you think the sediment in milk is likely to be?

2. Would there likely be bacteria in the filth in which cows have been lying?

Observations. — 1. Rinse out a recently emptied milk bottle

with water, stopper, and set it aside in a warm place. Note the odor after 10 or 12 hours.

Note. — Any odor will surely indicate the presence of bacteria, although they *may* be present *without* an odor.

2. Rinse another recently emptied milk bottle with cold water, then with boiling water, and finally scald it by boiling it in a pot of water for 5 minutes. Drain it well, stopper it, and set it aside as the first one. Note odor as before.

Conclusions. — 1. What care should be observed with vessels that have contained milk?

2. What is the effect of high temperature on bacteria in milk?

Questions

1. Why coat eggs with paraffin or soluble glass (sodium silicate)?

2. Why are hams and bacon smoked?

3. How is it that such an animal as the mammoth has been found entire and in a good state of preservation in Siberia?

4. Explain the principle of sour and sweet pickles.

5. Explain the advantage of the following method of canning fruits. Put fruit and a sufficient amount of sugar to suit in jars, cover them loosely, and set them in an oven for heating or in a boiler with a few inches of water and boil the water for a half hour. See that the boiler is closed, also that the jars do not stand directly on the bottom of the boiler. Place a cloth under them, or some strips of wood, to prevent breakage.

6. Why should pasteurized milk be cooled at once?

7. What is the principle of drying foods to make them keep?

8. Explain the Italian proverb, "Where the sun does not come the doctor does."

Special Reports

1. The importance of decay.
2. Pasteurization.
3. The importance of wholesome milk and how to attain it.

4. Some useful bacteria.
5. Conditions of growth of bacteria.
6. Raising germs for profit.
7. Some common disinfectants.
8. Indispensable bacteria.

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PROBLEM XXIV

A study of some biological relations of plants and animals.

a. The Balanced Aquarium (A Food Relation)

Observations. — 1. What have you learned is formed and set free when water-living plants (algæ) are exposed to sunlight?

2. What do animals need that is commonly obtained from the air?

3. Do you think that water animals need the same substance? If so, where might it come from?

4. What gas is given off from the lungs of man? *Note.* — The same gas is given off by all other animals, — by very small animals through the cell wall, by fishes through the gills, etc.

5. Do plants use this gas? How do they use it?

6. Animals also give off certain nitrogenous wastes, such as urea and ammonia.

Conclusions. — 1. How may the fishes in an aquarium obtain the necessary oxygen for respiration or breathing?

2. How might the oxygen get into the water?

3. Where might the plants in an aquarium obtain necessary carbon dioxide? Nitrogenous matter?

4. Itemize briefly how the plants and animals of an aquarium might be helpful to one another.

Observations. — 1. As snails feed on plants, and small water animals and tadpoles may feed on the decaying plant and animal matter that is likely to collect, they may be used as the animal life of a fresh-water aquarium. A small goldfish might also be added.

FIG. 38. — A balanced aquarium.

2. As such plants as algæ and other water plants grow at least as fast as they are devoured by the snails, it would seem desirable that they be used as the plant life needed.

Conclusions. — 1. Fill in the following summary. Do the two columns balance?

2. What is a 'balanced aquarium'?

BALANCED AQUARIUM

CONTENTS	INCOME FROM	OUTGO TO
Animals		
Plants		

b. Relations between Green Plants and Animals (The Energy Relation)

Observations. — 1. Study Figure 39 carefully. Just what forms the food material of plants possessing chlorophyll?

2. What forms the food of animals and plants without chlorophyll?

3. What becomes of the food mentioned in No. 2?

4. What are the bacteria of decay?

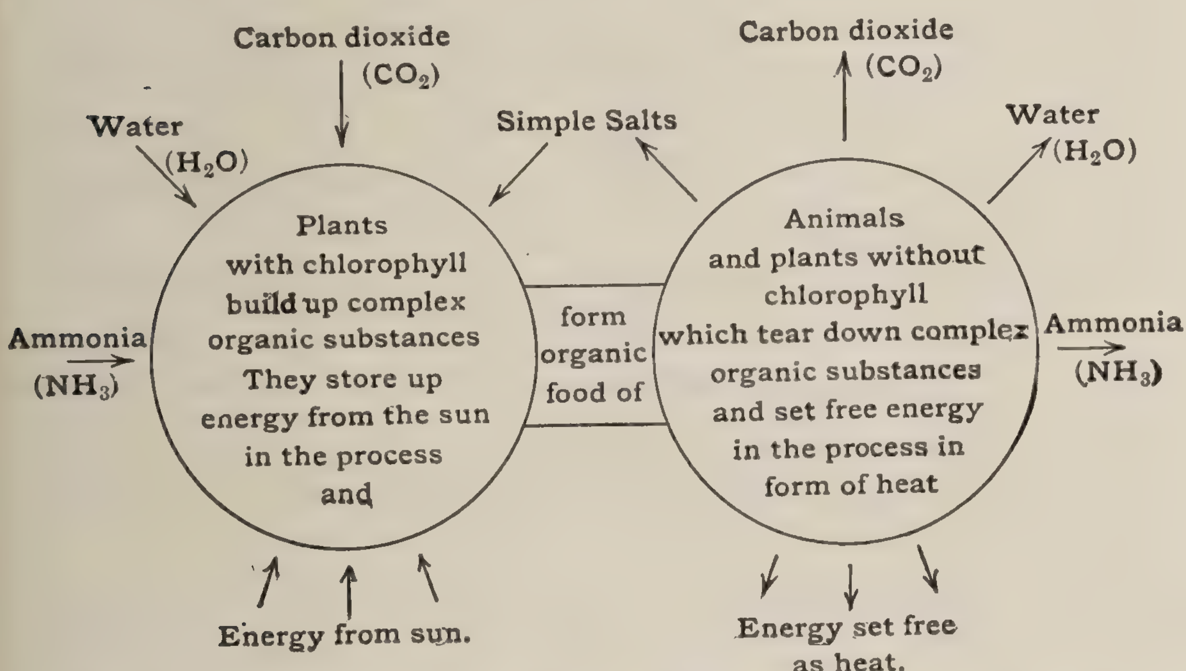

FIG. 39. — Relations between green plants and animals. (After Colton.)

Conclusions. — 1. How are plants able to store up energy? What finally becomes of it?

2. What is the energy relation between plants and animals as shown above?

c. The Nitrogen Cycle (The Nitrogen Relation)

Method. — Begin at the statement "Free N." and trace Figure 40 in the direction of the arrows.

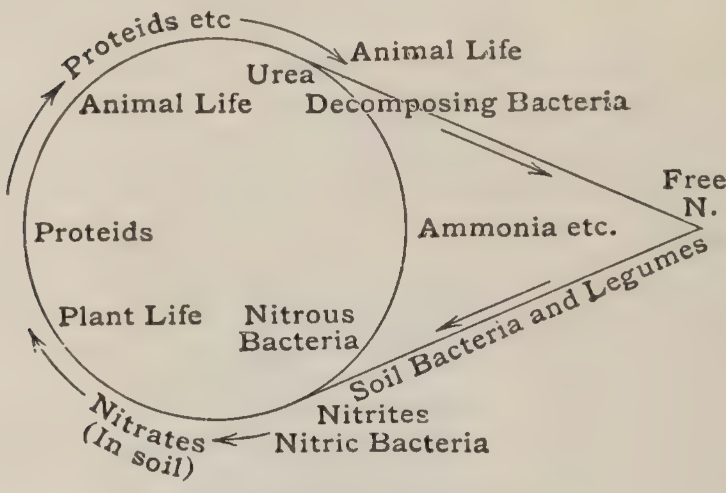

FIG. 40. — The nitrogen cycle.

1. Where is free nitrogen to be found?

2. What is the only way that free nitrogen may be obtained from plants?

3. What do plants manufacture in addition to starch that becomes available for animals?

4. What waste substance containing nitrogen is being constantly set free from animals?

5. What causes dead animal tissues to break up into their parts?

6. What are some of these parts? What becomes of them?

Conclusions. —1. What are the two most important links or factors in the nitrogen cycle?

2. Write a paragraph explaining what is meant by the 'nitrogen cycle.'

3. Try filling out a final summary in tabular form, somewhat as follows: —

		INCOME OF ANIMALS FROM	OUTGO FROM ANIMALS TO
Plants . . .	Green . .		
	Bacteria .		

d. A Hay Infusion (Another Food Relation)

Observations. — 1. Make a hay infusion as in the preceding problem. Let it stand a few days. What is the change in color? Appearance? Odor?

2. Is there a scum on top? If so, what does it indicate?

Conclusions. — 1. What is a tea infusion? Similarly, what is a hay infusion?

2. How do you think bacteria came to be in the hay infusion?

3. Where did the bacteria come from?

4. On what may the bacteria feed? What is the result of their action?

Observations. — 1. With a bulb pipette put a small drop from the scum on a glass slide and examine it with a low power of the microscope.

2. Do you see small one-celled animals moving about?

Note. — If corn meal is scattered on the scum, any small animals present, as *paramœcia*, will congregate about the meal to feed. Dipping near the bit of meal will then more surely result in getting numbers of paramœcia or other one-celled animals.

Conclusions. — 1. Where must the one-celled animals have come from?

Note. — Grass for hay is commonly grown near pools or wet places that dry up about haying time. These places practically always contain one-celled animals (*Protozoa*) that *encyst* themselves as they dry up, much as the resting spores of spirogyra or molds do; when this happens, they are blown about with the dust.

2. How do these encysted forms resemble seeds?

3. What causes seeds to awaken? What then likely caused these little dormant one-celled animals to awaken in the infusion?

4. Write a paragraph telling just why hay is used in the above manner in order to get one-celled animals for study.

Special Reports

1. The best aquatic plants.
2. Life in an aquarium.
3. The nitrogen cycle.
4. The balanced aquarium.
5. Life in a hay infusion.
6. Indispensable bacteria.
7. Animal and plant relations.

Questions

1. What is the use of chlorophyll to a plant?
2. Where do animals living in water get their oxygen?
3. What relations exist between animals and plants in regard to food?
4. Show in detail what is meant by the 'nitrogen cycle.'
5. Only how can plants use the free nitrogen of the air?
6. What two sorts of bacteria may well be known as indispensable? Show why.
7. What substances are set free when animal tissues decay?
8. Show how paramœcia and other one-celled animals may be obtained in the laboratory.
9. Why do some Protozoa encyst?
10. Show why marine Protozoa do not need to encyst.
11. What are the relations between the animals and plants in a hay infusion?

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THE PHYSIOLOGICAL UNIT AND DIVISION OF LABOR

PROBLEM XXV

To study a one-celled animal, in order to understand better the unit of animal structures.

Apparatus. — Pipette, glass slides and cover glasses, and compound microscope, charts showing methods of reproduction, etc., hay infusion.

Method. — Place some of the cloudy material from an infusion of hay or grass on a glass slide, cover with a cover glass, and study with low power of the microscope. (Look for paramœcia.)

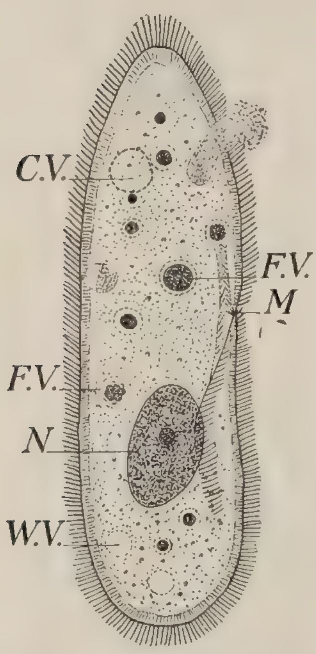

Fig. 41. — Diagram of a paramœcium. *F.V.*, food vacuole; *C.V.*, contractile vacuole; *M*, mouth; *N*, nucleus. (After Sedgwick and Wilson.)

a. In its Relation to its Surroundings

1. Reactions to Stimuli

Observations. — 1. Look carefully for small whitish animals moving rapidly about — much as shown in Figure 41. Do they move with any certain end first?

2. What shape has one of these animals?

3. Are they able to bend their bodies?

4. Do they seem to be able to avoid any obstructions?

5. Do they seem to congregate in any places in particular?

6. What seems to be the method of locomotion? [1] *Note.* — Here refer to Figure 41, and find the *cilia*, or fine vibratory hairlike structures.

[1] The instructor may demonstrate cilia if time permits, although it is not considered necessary.

Conclusions. — 1. Does there seem to be an *anterior* or head end as distinguished from a *posterior* or tail end? Explain.

2. Are these animals sensitive to their surroundings; that is, do they *react,* or *respond,* to *stimuli?* Reasons for your decision?

2. Feeding (Optional)

Note. — The food balls are small masses of food distributed throughout the body.

Method. — Run a mixture of carmine and water under the cover glass.

Observations. — 1. Look for a diagonal groove where the food is taken in (*gullet*).

2. Can you make out any movements of cilia here as indicated by the carmine grains?

3. In course of time, do you find any food balls within the body, as indicated by the carmine?

Note. — The masses of food appear to be inclosed in small areas, containing fluid, called *vacuoles.*

3. Contractile Vacuoles (Excretion) (Optional)

Note. — Other vacuoles, round clear openings, besides those containing food, can commonly be seen, which are supposed to act to pass off waste material from the cell body. These are called *contractile vacuoles.*

Observations. — 1. See if you can make out any changes in the shape of these vacuoles.

2. Do they close at times?

4. Reproduction (Optional)

Observations. — 1. Look for animals pinching into two parts, dumbbell fashion. (If the material does not show it, refer to page 192, Hunter, *Essentials of Biology.*) This is known as reproduction by *division.*

2. Likewise can you find any fused together lengthwise side by side? This is known as *conjugation.*

Conclusion. — Sum up the method of reproduction in a paramœcium.

b. As a Cell (Optional)

Method. — Use prepared slides or Figure 41. Can you find a cell wall? How can you tell nucleus from cytoplasm?

Drawings (Optional)

1. The paramœcium as a cell. Label everything shown.
2. Showing the different methods of reproduction.

c. In its Relations to Man

Observations.—Fill in the following tabulation as far as possible. See references below.

Disease	Means of Transmission	Where Found	How Prevent
Malaria			
Smallpox			
Sleeping Sickness .			
Spotted Fever . .			
Chronic Dysentery			
Rabies			
Measles			
Chicken Pox . .			
Texas Fever . .			
Kala Azar . . .			
Nagana			
Surra			

Questions

1. What is the meaning of the word Protozoa?
2. What is a cell?
3. What is protoplasm? Nucleus? Cell wall?
4. Where are Protozoa found?
5. How do Protozoa reproduce themselves?
6. Why are Protozoa so universally distributed?
7. How do Protozoa get rid of waste? How eat? How breathe?
8. What is meant by encysting? The purpose of encysting?
9. What is an amœba? How does it move, eat, reproduce, and get rid of waste?

10. What is said to be the cause of malaria?
11. What are trypanosomes?
12. Tell of the use of Protozoa as food.
13. Tell of Protozoa and rock building. What is chalk?
14. Explain the statement, "The cell is a unit."
15. How do Protozoa respond to stimuli?
16. Distinguish between Protozoa and Metazoa.
17. Why are Protozoa of great importance to the world?
18. What is tripoli?
19. What are parasitic Protozoa?
20. What is a hay infusion?
21. Explain: "The basis of all the life in the modern ocean is found in the microörganisms of the surface."

Special Reports

1. The formation of chalk.
2. Protozoa and malaria.
3. The tsetse fly and sleeping sickness.
4. Barbados earth. Infusorial earth.
5. The relation of Protozoa to higher forms of life.
6. The importance of Protozoa to man.

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PROBLEM XXVI

An introductory study of many-celled animals (Metazoa).

Method. — Develop the idea of the many-celled gastrula from the fertilized egg by using models, diagrams, etc.

a. Development

Observation. — What is the beginning stage of existence of a fern? Moss? Tulip? Bird?

Conclusions. — 1. Write a paragraph on the subject of Fertilization.

2. What must happen to the egg before it will develop? *Note.* — You will recall that the sperm cells of the moss and fern are motile, and that the egg is much larger and not motile. Here is a fine example of a physiological (functional) division of labor, which well meets the demand that one conjugating cell be very motile, and therefore comparatively small. Thus the sperm cells can swim to the eggs in the water where they are commonly set free. Another demand is that there be a sufficient supply of food to enable the plant or animal embryo to develop until such a stage of growth that it may care for itself. So food is stored in the egg, thus making it comparatively large and so hindering any great degree of independent movement. Remember that sperm cells and eggs are single cells.

Observations. — 1. After fertilization the egg divides into two parts, then these two divide, finally forming four cells, then 8, 16, 32, etc., until it is much like a hollow ball. How many layers of cells are there? Are the cells now all of the same size? *Note.* — The hollow ball stage is known as the *blastula* stage. See Figure 42.

2. Note that the hollow ball sinks in where the cells are

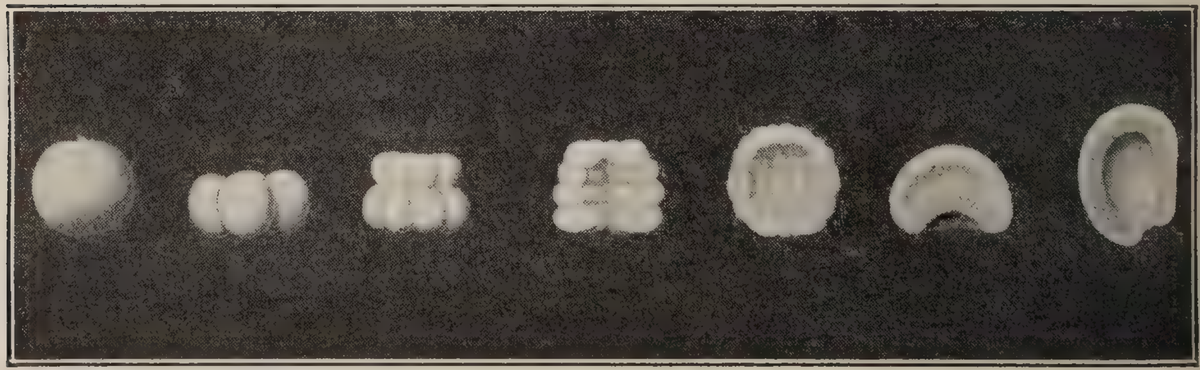

Fig. 42. — Stages in the segmentation of an egg, up to the formation of the gastrula.

the largest, until the side pushed in reaches the other side, thus forming a cup. How many layers to the walls of the cup? *Note.* — This stage is known as the *gastrula* (little stomach) stage, as the inner layer of cells commonly acts as a feeding organ (*stomach*).

Conclusions. — 1. What is the main difference between a single cell and a gastrula?

2. If the inner layer of cells of a gastrula function as a stomach, where is the mouth? *Note.* — Practically all animals above the one-celled ones pass through the stage just mentioned up to the gastrula stage, and then develop into the special animal concerned.

b. Sponges

1. Grantia

Material. — Small vials of grantia, hand lenses, toilet sponge.

Observations. — 1. Find needle-like or bristle-like structures (*spicules*) forming the skeleton of the sponge.

2. Can you find a system of canals and cavities for the passage of water?

3. Find a large opening at the free end (the *osculum*).

4. Examine a sponge split lengthwise, and one cut crosswise, and find the central space or *cloaca*.

5. Note the small passage through the body wall leading from the outer surface to the central cavity. The external openings of these canals are called *inhalent pores*, and the internal openings are called *ostia*.

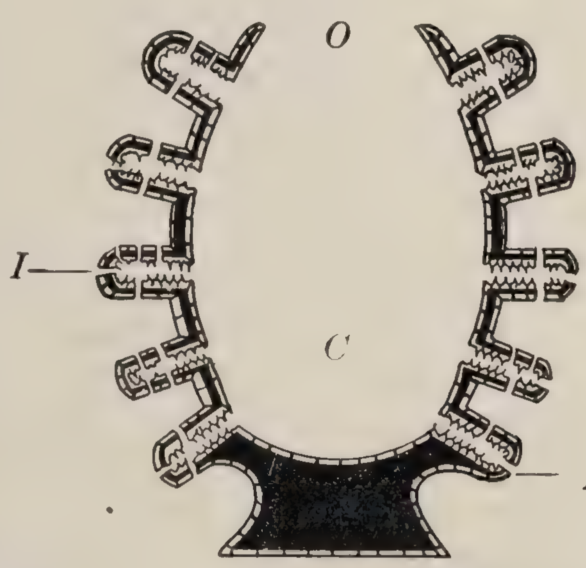

Fig. 43. — Diagram of plan of structure of a sponge. *O*, osculum; *I*, inhalent pore; *C*, cloaca.

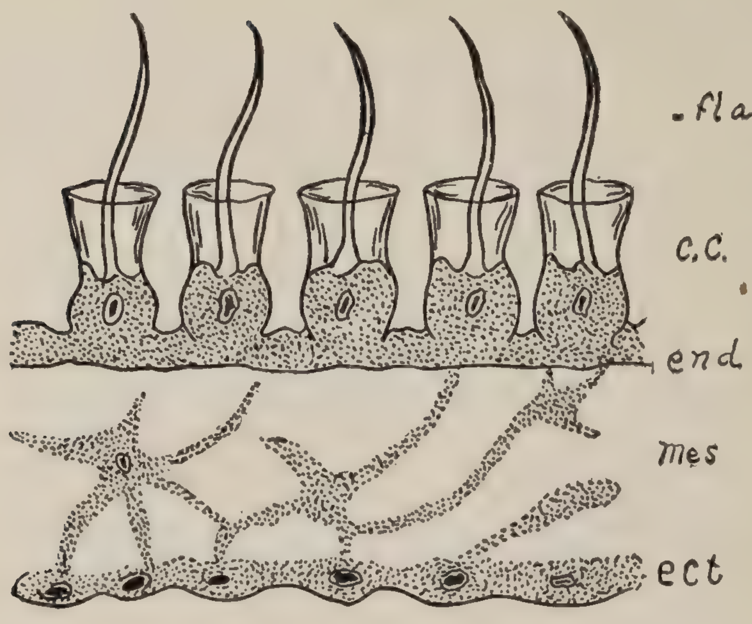

FIG. 44. — Section through sponge wall. Showing *fla*, flagella, the vibrations of which cause currents of water to flow through the sponge.

Conclusions. — 1. What seems to be the purpose of the inhalent pores? Of the canals?

2. What is the course of the water through the canals? Refer to Figure 43.

3. What causes the water to flow through the canals? See Figure 44.

4. How might you compare a sponge with the city of Venice?

5. Show that special parts of a sponge have special duties (*division of labor*).

2. Other Sponges (Optional)

Material. — Small bits of sponge skeletons, slides and cover glasses, portable microscopes, hydrochloric acid, chart.

Method. — Mount bits of the skeleton of grantia and a toilet sponge, and examine with low power. Also test them with acid.

Observations. — 1. Which spicules are needle-like, and which are much branched?

2. Which feel the most elastic to the touch?

3. Which sort of sponge absorbs water the most readily?

4. What is the effect when grantia spicules are put in acid? The toilet sponge? When each are burned?

5. What can you say about the odor of sponges.

Conclusions. — 1. Why is the toilet sponge an article of commerce, rather than the other?

2. How does a sponge appear to be protected from fish and other animals?

c. The Hydra (Optional)

Observations. — 1. Observe living hydras, either in a small aquarium or in Syracuse watch glasses.

2. What is their shape? *Note.*—Study Figure 45 or a chart. Note that the body of a hydra is hollow, and with but one opening at the free end of the body, that serves both as a mouth and as a means of getting rid of waste.

3. How many threadlike organs (*tentacles*) do you find about the mouth?

Conclusions.—1. Compare a hydra with a gastrula, showing how they resemble each other. *Note.*—The gastrula stage of most water animals is ciliated so that it may swim about until it finally settles down to develop further,—either with very little added differences, as in the hydra, or many added changes in order to form higher and more complicated animals.

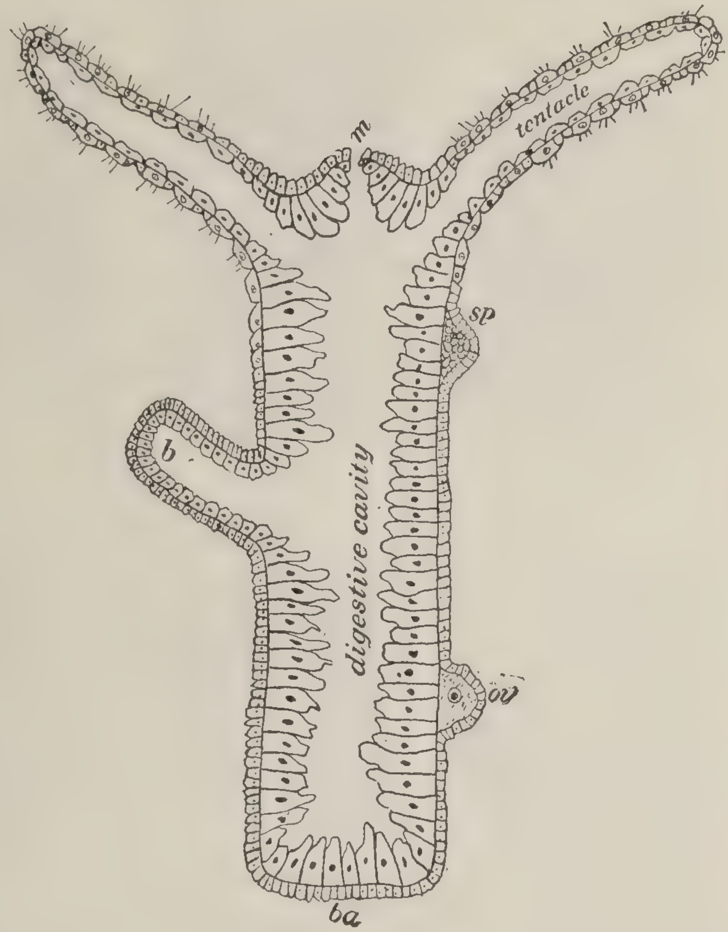

Fig. 45.—Lengthwise section of hydra; *ba*, attached end; *b*, bud; *m*, mouth; *ov*, ovary; *sp*, spermary holding sperm or male cells.

2. Study a longitudinal section of a hydra, and show how it is much like a gastrula.

3. Show how certain parts of this animal have certain duties to perform (*division of labor*).

4. In what respect does a hydra agree with a sponge?

5. Which have the better arrangement for getting food and oxygen, Protozoa living singly, or many ciliated cells side by side, as in the sponge? Which have better opportunities for development?

d. The Development of Tissues and Organs

Observations. — 1. We have previously learned that cells doing the same sort of work are said to form *tissues,* such as muscle tissue, nerve tissue, protecting tissue, etc. How many

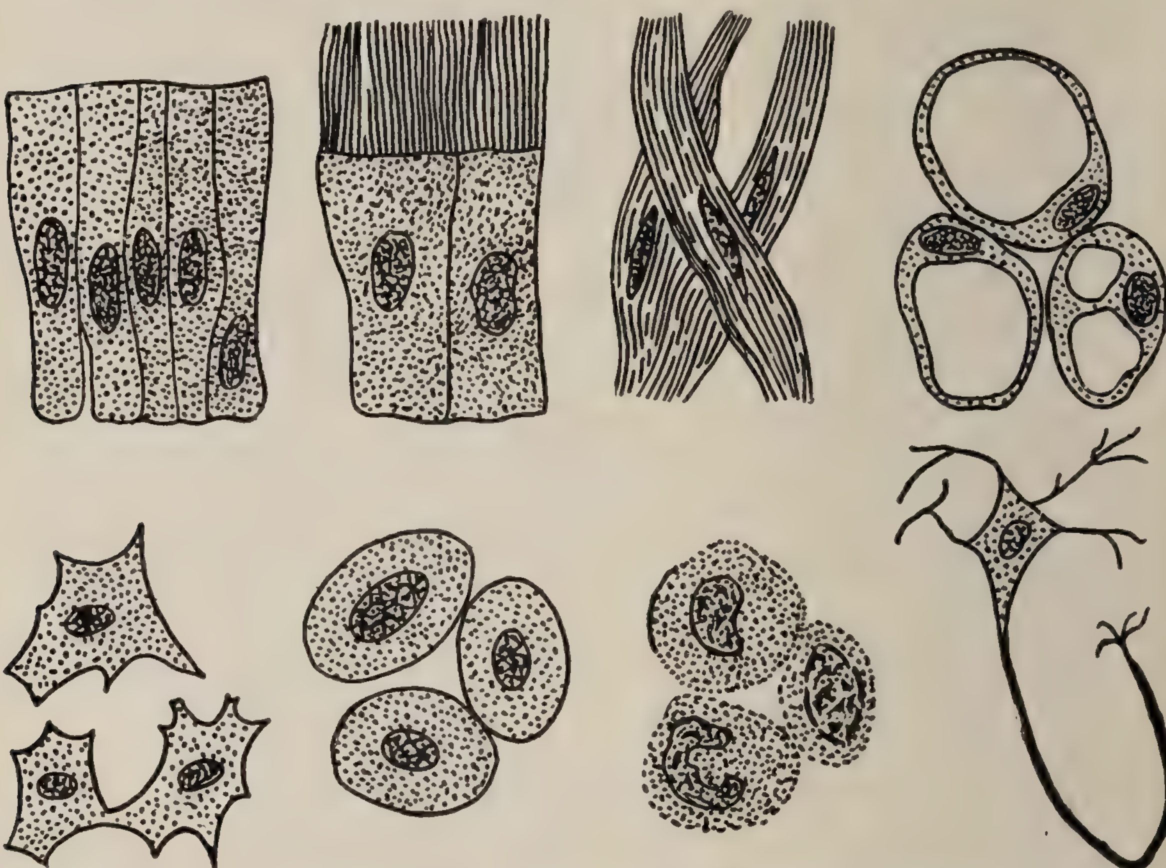

FIG. 46. — Different sorts of cells; some results of division of labor.

tissues in a gastrula? What are they? *Note.* — A tissue is a set of similar cells for a special purpose.

2. Examine Figure 46 or slides showing different kinds of cells, such as of muscle, nerve, bone, etc. Are they formed for the same or different functions? See also Figure 9.

3. What tissues have you noted in a hydra?

4. Name some tissues that are likely in your hand. *Note.* — Organs are special sets of tissues, each for a special purpose, as the hand, the eye, the ear, the stomach, etc.

Conclusions. — 1. If organs are made of tissues and tissues of cells, what is your conclusion?

2. What is the purpose of different sorts of cells in the body?

3. Show that, if cells represent soldiers, the body is a well-disciplined army, with many divisions for different sorts of work, — these divisions made of different regiments, but the regiments of individuals working in harmony.

e. Common Functions

Observations. — 1. What must a one-celled animal do in order to live? (Review paramœcium.) *Note.* — The necessity for food implies a need of the means for getting it, such as organs of locomotion, nerves, sense organs, etc. After food is obtained it must be digested, then carried about the body (*circulation*) and the waste eliminated (*excretion*), etc.

Conclusions. — 1. Name the organs and functions common to all animals so far as you know them.

2. How does a one-celled animal compare with a man in the number of its organs, and, therefore, the degree of bodily or physiological division of labor?

3. Fill in the following tabulation. Tell means of performing the common functions, as far as possible.

Common Functions	Paramœcium	Sponge (Option)	Hydra	Man (Option)
Food taking . .				
Digestion . . .				
Circulation . .				
Respiration . .				
Excretion . .				
Locomotion . .				
Nerve control .				
Senses				
Nerves				
Reproduction .				

4. Which one is the better organized, and therefore the higher animal? Reasons for your answer?

Questions

1. Where are the sponge cells in an ordinary commercial sponge?
2. How are toilet sponges prepared for the market?
3. How and where are toilet sponges obtained?
4. How do the individual sponge cells get their food and oxygen?
5. How does a sponge show division of labor?
6. Where are the most important sponge fisheries?
7. Tell, step by step, how a fertilized sponge egg becomes a blastula, then a gastrula, and finally a stationary sponge.
8. Show how there is division of labor in a hydra.
9. What are the functions common to all animals?
10. What is the cell theory?

Special Reports

1. The sponge industry.
2. The development of Metazoa to the gastrula stage.
3. Division of labor in a metazoan.
4. The cell theory of Schleiden and Schwann.

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SOME REACTIONS AND ADAPTATIONS AMONG ANIMALS

PROBLEM XXVII (OPTIONAL)

The relations of the earthworm to its surroundings.

Materials. — A shallow tray, moist blotting paper, hand lens, ruler, a pasteboard cover to fit tray, bristles, living earthworms.

a. External Appearance

Method. — Place living worm in the shallow tray on moist blotting paper.

Observations. — 1. Is it an active or sluggish animal?

2. What is its general color?

3. What advantage to the worm is the relation of its color to the color of the earth?

4. What is its general shape? What is its symmetry?

5. How should you identify the anterior end?

6. How does the dorsal surface differ from the ventral surface? On which surface does the worm crawl?

7. Find the broad band (*girdle*) near the anterior end.

Conclusions. — 1. How distinguish the anterior from posterior end?

2. How does the earthworm resemble other animals you have studied? How does it differ?

3. How may it escape its enemies?

b. Motions

Observations. — 1. Measure the shortest length and the greatest length of the same worm.

2. Examine and compare the regions of expansion and contraction as the worm moves forward.

3. Run your finger lightly over the ventral surface of the worm. What do you feel? (Use specimens preserved either in (1) formalin or (2) alcohol, then dehydrated, then run into xylol, and then dried.)

4. Examine the ventral side with a hand lens and identify the projecting bristles (*setæ*).

Conclusions. — 1. How are contractions and expansions concerned in the forward motions of the worm?

2. What prevents a worm from slipping while crawling?

c. Nervous Responses to Stimuli

Observations. — 1. Gently touch various parts of the worm with a blunt bristle.

2. Observe a moving worm carefully. How does it find its way? Is the "lip" a sense organ?

3. Place the worm in a tray and partially cover it with the pasteboard cover. Observe whether the worm prefers light or darkness.

4. Tap the tray with your pencil. Does the worm respond?

Conclusions. — 1. What do you think regarding its responses to touch?

2. What about its responses to light?

3. Does a worm hear or feel in responding to a jar?

4. Which portions of a worm are the most sensitive?

d. Blood Tubes

Observations. — 1. Look for a dorsal red tube which pulsates. This is the dorsal blood vessel which can be seen through the semitransparent body wall.

2. Examine the region about the girdle for several pairs of lateral red vessels, the so-called "hearts."

Conclusions. — 1. Does the blood move in any definite direction as indicated by the pulsations?

2. How might oxygen get into the blood tubes you can see?

Questions

1. Why cannot earthworms live in a dry place?
2. How do earthworms enrich the soil?
3. Do they injure plants or animals?
4. How are earthworms protected from their enemies?
5. What is the effect of the parasitic habit on such a worm as the tapeworm?
6. In what different ways do worms get their food?
7. What is meant by the term "regeneration" as applied to worms?
8. What are some of the most dangerous worm parasites to man and the domestic animals?

Special Reports

1. Economic importance of the earthworm.
2. Economic importance of worms in general.
3. Reactions of the earthworm.

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PROBLEM XXVIII

A study of some animal associations.

a. Social Life (Optional)[1]

Note. — Mutual aid and equal dependence is the basis of all social life among animals.

Observations. — 1. What have you observed concerning the social habits of birds, such as the English sparrow?

2. Do geese and ducks usually fly singly or in flocks?

3. What do you know about similar habits of the buffalo or wild cattle and horses?

Conclusions. — 1. If a flock of birds should be scattered, would the individual birds be likely to die? Explain your answer.

2. What do you imagine was the reason for the herding of such animals as the wild horse and the buffalo?

3. Do the individuals of these groups do special and different kinds of work for the society, or are they all mutually and equally helpful? Explain.

4. Show how social life is of advantage to the individuals of the group.

b. Communal Life (Optional)

Note. — Animals of the same kind that coöperate form *communities*, whenever the work they do for the community is of different sorts, or there is division of labor.

[1] The exercises under a, b, and c may well be made the basis for a trip to a museum or a zoölogical park.

Observations. — 1. By means of specimens or chart, note the different kinds of individuals in a colony of bees. Are they all alike? If not, how do they differ?

2. Examine a paper wasp's nest or study Figure 47. Also examine a termite's nest, or at least a Figure of one as in Thompson's *Animal Life*, page 86. Do these nests show evidences of skilled work? Show if there is division of labor in these communities.

FIG. 47. — Hornets' nest, opened to show cells of the comb. A result of animals working for the welfare of the community. (After Overton.)

Conclusions. — 1. Do the individuals of these groups work for the benefit of themselves solely, or mainly for the good of the community?

2. Sum up the benefits of communal life to animals.

3. Which is the most effective relationship of the two just studied?

c. Commensalism or Symbiosis (Optional)

Note. — Many animals of *different* kinds coöperate and mutually help one another and in this way are more successful in the struggle for existence. This is known as *commensalism* or *symbiosis.*

Observations. — 1. Examine specimens of hermit crabs with sea anemones on their shells. If no specimens are available, study Figures 105 and 106, Jordan and Kellogg, *Animal Life.*

2. Many sponges are said never to be found except on the backs and legs of certain crabs. Where do sponges ordinarily grow?

Conclusions. — 1. Show how sea anemones with thousands of stinging cells might be of advantage to crabs.

2. Might the sea anemones be helped in any way?

3. Show how sponges and crabs might be mutually helpful.

d. Parasitism

Note. — Many other animals have taken to a thievish existence as unbidden guests in or on the bodies of other animals. The "thieves" are called *parasites* and the animals preyed upon are known as *hosts.* In this relation the parasite sometimes gains all the necessaries of life, while the host gains nothing, and may even lose its life.

1. Grades of Parasitism

Observations. — 1. Fleas on cats and dogs are known as *temporary external parasites.* Do they necessarily remain on one animal?

2. Chicken or bird lice are known as *permanent external parasites,* as they remain on one host until death of parasite or host.

3. Many crustaceans, insects, and worms live within the bodies of their hosts. These are known as *internal parasites.* Many times two hosts are necessary. The tapeworm lives in man until eggs are set free, then the eggs are eaten with food by cattle or pigs, then the young worms eaten in underdone beef or pork and thus taken into the body of man again. Here man is the *host* and the cow or pig is known as the *intermediate host.*

2. Probable Causes and Advantages of Parasitism.

Observations. — 1. Show how the females of chicken lice or fleas may be better off than they would be if free-living.

2. Show how it may be easier for parasites to get their food supply than if they were free-living.

Conclusion. — Tell as many of the causes and therefore advantages of parasitism as you can.

3. Some Parasitic Worms

Observations. — 1. Examine a tapeworm, or study a Figure of one. Note its segmented shape. How long do these worms grow?

2. Note that the segments farthest from the small (head) end are the largest. They contain the eggs of the worm, and as they ripen the segments are set free and pass from the body of the host (man).

3. Suppose these eggs or young become scattered about where cattle and hogs are feeding. What may happen?

4. The young are provided with hooks and are able to bore through flesh. What do you think is the purpose of the hooks?

Conclusions. — 1. Suppose uncooked or underdone beef or pork containing the young of these worms should be eaten by man. What part of man might be infested with them? Would man be the host, or intermediate host?

2. What is evidently one of the best means of preventing these worms from entering the human body?

3. Write a paragraph telling all you know of the tapeworm.

Observations. — 1. Examine some encysted trichinæ. (Use mounted specimens or study Figures.) They may sometimes be found in the flesh of the hog or other host.

Note. — As many as 120,000 to a cubic inch may sometimes be found in the flesh of the pig.

2. Suppose some underdone pork containing trichinæ is eaten by man, and each female worm now produces from 600 to 1200 young that proceed at once to bore through the walls of the stomach and intestines of man to the surrounding muscles. The man complains of cramps, rheumatic symptoms, and much irritation of the muscles. He is suffering from the disease known as *trichinosis.*

Conclusions. — 1. What precautions should be observed before eating pork?

Note. — Government inspection of meats does not now surely include inspection for trichinæ.

2. Rats are likely to be infested with trichinæ. How may cats and dogs become likewise infected?

3. Has an intermediate host been mentioned for the trichina?

Write a paragraph summing up all you know about the trichina.

Observations. — 1. Examine a slide of the hookworm (*Uncinaria americana*), and Figure 48. See if you can tell why it is called the hookworm.

2. In addition to hooks for hanging on to the lining of the intestine, these worms are provided with a fanglike hook for drawing blood from their victim. This fanglike hook is also poisonous. The poison is supposed to prevent the blood from clotting that runs from the small wounds they inflict. How might continuous bleeding from small wounds at last affect the host?

Fig. 48. — Anterior end of a hookworm. Note the tiny hooks on the anterior end. (Photograph by Mr. J. J. Schoonhoven.)

Note. — As many as from 600 to 4000 have been found in the bodies of their victims.

3. The poison set free is also said to affect the red marrow of the bones where much blood is made. How might the victims indeed become lazy?

Conclusion. — Explain how the hookworm came to be called the "lazy worm."

Observations. — 1. The female hookworm lays her eggs in the intestines of her victim, but they cannot develop without oxygen. They therefore pass from the body to hatch.

2. More than 70% of the "poor whites" and negroes of the South have no toilet closets. The few there are might be easily accessible to pigs and chickens. How might hookworm larvæ be scattered through the damp soil?

3. The larvæ of these worms are able to bore through the skin through the hair pores.

Conclusion. — Explain how the larvæ of the hookworm may readily infect the children of the poor. Show how the wearing of shoes would be of value. See Figure 49.

Fig. 49. — A family of poor whites in North Carolina. All infected with hookworm disease.

Observations. — 1. The hookworm was undoubtedly brought to this country by the negro slave. More than 90% of the negroes of the South are infected to-day, but they are more immune than the whites. What is the meaning of the term 'immune'?

2. More than two million of the poor whites of the South are infected. Can they be permanently cured without at the same time also curing the negroes? Explain.

Note. — The best remedy is thymol, followed a couple of hours later by Epsom salts. The thymol stupefies the worms, causing them to loosen their hold, and the Epsom salts later cleanse them from the intestines. *Caution! thymol should not be given without the advice of a physician.*

Conclusion. — Since most poor whites and negroes of the South are renters, and too poor and ignorant to furnish toilet facilities, where must we place the responsibility for the cure of the hookworm disease?

4. Some Effects of Parasitism

Observations. — 1. Does a tapeworm have any use for legs? Of a food canal? Of a digestive system? Explain your answer in each case.

Note. — The general effect of parasitic habits is to cause the loss of the use of most of the organs of the body. This is called degeneration. The use of the organs really *makes life worth living.*

2. If a tapeworm does not need to move about, is there any need of sense organs?

3. If there are no sense organs, is there need of a well-developed nervous system? Explain.

Conclusion. — Show whether there could be much or any real enjoyment, or zest of life, where there are no sense organs or well-developed nervous system.

5. Human Degeneration

Degeneration means a loss of complexity, and a corresponding loss in ability to accomplish the real business of life. In man it commonly means the weakening or complete loss of all intellectual and moral qualities. High development in man and in civilization is dependent on intellectual and moral excellence.

Observations. — 1. Does a tapeworm need to depend on its own exertions in order to get its living? Is it dependent or independent?

2. What is the result of this life on the powers and capabilities that it otherwise might possess?

3. What is meant by the statement "Independence favors complexity of power"?

4. Explain the statement "Degeneration has been called animal pauperism."

5. A tendency to live without self-activity is inherited among men, due to the desire to live at the expense of others. What is meant by the term "beggar"?

Conclusions. — 1. Show how a beggar is a human parasite, and therefore a degenerate. Should he be helped without any return? Explain. *Note.* — Persons unable to provide for themselves are taken care of by society, and hence are not obliged to beg.

2. Explain how an idle or pampered person may lose the use of some of his powers.

3. Show how men should not seek to withdraw from the competition of life.

4. Which sort of life should give the most pleasure and satisfaction to a normal human being, — an idle life, or an active life? Explain.

5. Is a man who inherits large sums of money and invests it and lives on the income, a parasite? Explain.

6. Is a boy who hinders teachers in class work, by inattention, whispering or disorder, a parasite? Explain.

Questions

1. Distinguish between social and communal life, and give examples of each.

2. How may parasitic habits have been acquired?

3. Name some parasites of domestic animals.

4. What is an intermediate host?

5. What are the advantages of communal life?

6. Explain the use of the terms *symbiosis* or *commensalism*.

7. Show that division of labor is the basis of communal life.

8. Why must parasitic worms produce their young in great numbers?

9. Name some of the more dangerous parasites to man.

10. What is the life history of the liver fluke?

11. Why is the hookworm the most common among the poor and ignorant?

12. Name the best means of preventing hookworm disease.

13. Where are the hookworm regions of the United States? How were the worms probably introduced into this country?

14. Why have the poor whites of the South obtained the reputation of being lazy and without ambition?

15. Why is the hookworm disease so prevalent in Porto Rico?

16. How prevent infection from tapeworms and trichinæ?

17. Give the life history of the tapeworm.

18. What is the effect on man of the lack of self-dependence?

Special Reports

1. Symbiosis or commensalism.
2. Parasitism and degeneration.
3. The hookworm and means of fighting it.
4. Communal life amongst animals.
5. Human degeneration.
6. Tapeworms and their hosts.
7. The life history of the trichina.
8. The federal government meat inspection service.

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PROBLEM XXIX (Optional) [1]

A study of the idea of adaptations as shown in the crayfish.

Materials. — Living and preserved crayfish, deep trays of fresh water, pipettes, hand lens, vial of carmine solution or red ink, raw meat or beef juice, ammonia.

a. Protection

Method. — Place a live crayfish in a tray of water.

Observations. — 1. What is the general color of the crayfish?

2. Is it the same in all parts?

[1] This may well be the third problem taken if one desires to follow exactly the latest New York State Syllabus for Elementary Biology.

3. Name an animal that is active; one that is sluggish.

4. Is the crayfish an active or a sluggish animal?

5. Note its large pinching claws.

Conclusions. — 1. Can it be easily seen when at rest between water weeds or rocks.

2. What do you think is meant by the term 'protective coloration'?

3. What is evidently one use of the large claws?

b. Locomotion

1. Walking

Method. — Place the crayfish on the laboratory table, and observe its movements.

Observations. — 1. What is its attitude when you are trying to seize it?

2. Are the pincers (*chelipeds*) used in walking?

3. Notice the appendages used in walking. How many are there? (They are called *walking legs.*)

4. Do the walking legs on opposite parts of the body move together?

5. What seems to be the use of the long feelers (*antennæ*) during the locomotion of the crayfish?

Conclusion. — Write a paragraph telling how the legs are adapted (fitted) for their uses.

2. Swimming

Method. — Place specimen in a tray of water.

Observations. — 1. How does the specimen swim? (The organ used in swimming is called the *caudal fin.*)

2. Does the fin change its shape for either stroke?

3. Just how is the caudal fin used in swimming?

Conclusions. — 1. What can you say of the differences in function of the appendages just studied?

2. Would it be easy for the crayfish to swim forwards instead of backwards? Explain your answer. (How are ships retarded at sea?)

3. How is the shape of the caudal fin adapted for swimming? Compare with a paddle or oar.

4. Write a paragraph showing just how a crayfish is fitted or adapted for life in the water.

c. Surroundings (Reasons for Sense Organs)

Observations. — 1. Touch various parts of the body lightly with a pencil or bristle, and note the results. Try especially the joints and other thin parts of the body, the eyes, feelers, and mouth parts.

2. Note the feelers. The long ones are called *antennæ*, the short ones *antennules*. How are they arranged when the crayfish is at rest? When disturbed? When crawling?

3. Wrap a bit of cotton on a toothpick or splinter and dip in ammonia. Place this near various parts of the crayfish, especially the mouth parts and feelers, *but do not touch the crayfish with it.* Does the crayfish respond?

4. Move the point of a pencil slowly toward the front of one of its eyes. How does it respond?

5. How great is its range of vision? That is, through what part of a circle can a crayfish see without moving its body? Compare this with your own range of vision.

6. Place a cover over one half of tray. Where does the crayfish place itself with respect to light or darkness?

Conclusions. — 1. Name in order the parts of a crayfish that appear the most sensitive.

2. What seems to be the function of the antennæ and antennules?

3. Where do you think the sense of smell is located?

4. What advantage has the crayfish gained by having its eyes mounted on movable stalks?

5. What conclusions can you draw as to its sensitiveness to light?

6. Compare the sensibility of the crayfish with that of the worm. Which do you consider has the keenest senses?

7. Compare likewise with a cat or dog. Which is the better organized animal?

8. What light does the sensibility or reactive power of the crayfish throw upon its position among animal forms?

9. What do you think is the real reason for the presence of sense organs?

d. Feeding

Note. — A crayfish in captivity will not readily respond to offers of food, but with patience some results may be obtained.

Method. — By means of a dissecting needle or wire, convey a piece of beef or liver towards the mouth of the crayfish, and finally loosen it near the appendages there. Note the reaction. (Beef juice may be used in place of meat.)

Observations. — 1. What movements of the mouth parts do you see?

2. Does it make any use of its chelipeds?

Conclusions. — 1. What appendages do you judge are adapted for seizing food?

2. What appendages may guide the food like fingers?

3. What appendages may cut the food or bite it? The jaws on each

side of the mouth are called the *mandibles*. See any good figure or chart if no mounted mouth parts are available.

4. In what directions must the jaws move in biting food?

5. For what are the large claws fitted?

e. Breathing

Method. — Place crayfish in a tray with about one inch of water in it, and drop with a pipette a little carmine mixture or red ink between the bases of the walking legs. Or hold the specimen ventral side up, and do likewise, and replace in tray.

Observations. — 1. Tell just what was done in performing the experiment on respiration.

2. Did you observe any currents of colored water? If so, where? How many?

3. Did the currents flow steadily or in jets, if seen?

4. Now note the location of the gills in a specimen with part of the shell removed, prepared by the instructor.

Conclusions. — 1. What seems to be the cause of the colored currents of water? *Note.* — There are small paddle-like structures called *gill bailers*, that drive the water ahead.

2. Tell any reasons why you think the streams did not come out of the mouth.

3. What do you conclude is the course of the water that circulates through the gills? Where does it enter? Where leave?

Drawing. — Make a sketch showing the directions of the currents of water as they enter and leave the cavity containing the gills (*gill chamber*).

f. A Morphological Study (For Advanced Students)

1. General Characters of the Shell

Observations. — 1. What is the general shape of the body of a crayfish?

2. Note that the body is divided into two distinct parts or regions. The unsegmented anterior region is called the *cephalothorax*, while the segmented posterior region is called the *abdomen*.

3. Is the cephalothorax all in one place? The transverse groove separating the head proper from the *thorax* is called the cervical groove.

4. How many segments do you find in the abdomen?

5. Does the shell cover the entire body? In answering this question note carefully the joints. The shell is called the *exoskeleton*.

6. Drop a bit of the shell in dilute hydrochloric acid and observe the result. When this acid is placed on a substance and it effervesces or forms bubbles of gas, you may expect the substance to contain *lime.*

7. The shell over the dorsal part of the cephalothorax is called the *carapace.* It extends forward into a beak, called the *rostrum.* Find these parts.

8. Is the carapace continuous with the ventral portion of the shell?

9. Lift the edge of the carapace or cut it away from one side, and find the *gills* under the shell. The space inclosed by the overlapping of the shell is called the *gill chamber.*

10. How are the segments of the abdomen united with one another?

11. Has the tail segment, or *telson*, a pair of appendages? If not, how are they related to the telson?

12. Where is the skeleton of a crayfish located?

Conclusions. — 1. What is the most flexible portion of the body?

2. How is the abdomen adapted for flexibility?

3. What is the office of lime in a shell?

4. How is the caudal fin adapted for swimming?

5. Are the gills external or internal structures? Explain your answer.

6. What differences in habitat may be expected of the crayfish as compared with a worm, because of its well-developed skeleton? What differences in habits?

7. How can you tell the presence of lime in a shell or skeleton?

2. Appendages

a. The Eye

Observations. — 1. Note the eye stalk, and the eye at its tip. (Use hand lens.) Can it be moved in all directions?

2. Note the thick shell covering the *cornea.* Study a small bit of the cornea mounted on a slide in glycerine, using low power.

3. Note the small areas (*facets*) of which the cornea is composed. These mark the outer ends of the single eyes. Since the eye of a crayfish is composed of many such single eyes, it is called a *compound eye.*

b. The Legs

Observations. — 1. How many walking legs do you find? How many *chelipeds?*

2. To what region are the walking legs attached?

3. Bend each joint of a cheliped. In how many directions will a single joint of a cheliped move?

4. In how many directions will the entire leg move?

Conclusions. — 1. Compare the movements of your arm and the joints to accomplish these movements with the possible movements of a cheliped. Which has the better arrangement to secure a great range of movement?

2. Explain your answer in detail.

c. The Gills

Observations. — 1. Use a specimen which has had the sides of the carapace covering the gills removed. What is the general appearance of the gills?

2. Move a cheliped. Is there a corresponding movement of any of the gills?

3. Look in the anterior part of the gill chamber and find the "paddles" which bale the water through the gill chamber. How are they shaped?

4. Examine the lower edge of the carapace that covers the gills. What do you see?

Conclusions. — 1. Is there any advantage in the attachment of gills to the walking legs or mouth parts? If so, what?

2. How are the gill "paddles" adapted to their function?

3. Compare the method of getting oxygen in the sponge and crayfish. Is there any similarity? What?

4. How is the water strained as it enters the gill chamber?

Drawings

1. Side view of a crayfish, natural size, with carapace removed from one side to show gills.

Label: cephalothorax, rostrum, abdomen, eye stalk, antennæ, walking legs, chelipeds, gills.

2. Eye and stalk, and a few of the facets as seen through the microscope.

3. Walking leg with gill attached.

4. Drawing to show structure of abdomen and tail fin.

Questions

1. Crayfish are sold in large numbers in the markets of New York and other large cities. Where do they come from?

2. How can they be shipped long distances without water?

3. When is the breeding season of the crayfish? Of the lobster?

4. What other crustacea are of economic importance? In what ways?

5. Where are shrimps and lobsters obtained?

6. What peculiar habits have some crabs for self-defense?

7. Why are the small "water fleas," or Entomostraca, of great economic importance?

8. What is plankton? Why is its study considered important?

9. What are the Entomostraca? Name some examples.

10. Why do not crayfishes live in New England?

11. What is meant by ecdysis, or molting? Why must it take place in the Crustacea?

12. What about the supposed relationship of crayfish to floods of the lower Mississippi Valley?

Special Reports

1. Lobster fisheries.
2. The shrimp industry.
3. The crab industry.
4. Habits of hermit crabs.
5. Enemies of the lobster and crayfish.
6. The economic importance of crayfish.

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THE MOST SUCCESSFUL ANIMALS, INSECTS, AND THEIR RELATION TO MAN

PROBLEM XXX

A study of some animal likenesses and differences, and the classification of insects.

a. The Grasshopper or Locust (a Straight-winged Insect).

1. Body

Note. — This is an optional study if a living grasshopper was studied in Problem IV.

Observations. — 1. Note the regions into which the body is divided. They are called respectively the *head*, *thorax*, and *abdomen*.

2. To which region are the wings and legs attached?

3. Note the outer skeleton (*exoskeleton*). Is it flexible or hard and unyielding? It is composed mostly of *chitin*.

Conclusion. — Show whether an inside or outside skeleton would be best for a locust. *Note.* — Keep in mind their habitat amongst leaves, twigs, grass, etc., and that they can fly quite long distances.

2. Appendages

Observations. — 1. How many pairs of legs are there? How do they differ in size? Where are they located?

2. Note that each leg is made up of three principal parts, — the femur or thigh, the tibia or shank, and the tarsus or foot.

3. Find some hooks and pads on the tarsus.

4. What is the use of spikes on a runner's shoes?

Conclusions. —1. How do the legs probably differ in use? Give reasons from their position and structure.

2. What is the probable use of the hooks of the tarsus?

Observations. — 1. Where are the wings located?

2. What is the natural position of the wings when folded?

3. What is the relative position of the wings when outspread?

4. What differences do you note between the two sets of wings?

5. Observe that the margins of the fore wings are straight. Does an aeroplane resemble them in this respect? Are they tough?

Conclusion. — What is the probable difference in function of the two sets of wings?

3. Mouth Parts

Observations. — 1. Are the lips that cover the jaws movable?

2. With a lens note the teeth on the jaws.

Conclusion. — Which way must the jaws move in biting food?

4. Sense Organs

Observations. — 1. Note the length, shape, segmentation, and place of attachment of the "horns" (*antennæ*).

2. Find the large eyes. Where are they situated? Examine them with hand lens. Are they compound? Explain your answer.

3. Examine a section of a compound eye with low power of a portable microscope, and note the facets. Sketch a few of them.

4. Find a simple eye (*ocellus*) on the ridge between the antennæ? Find a similar one above each antenna?

5. Find a pair of ear membranes on the first segment of the abdomen. Lift the wings to find them.

Conclusions. — 1. Can a grasshopper see anything approach from behind? Explain?

2. Has a grasshopper the sense of hearing? *Note.* — Organs imply functions.

5. Respiration

Observations. — 1. Look for small breathing pores (*spiracles*) along the sides of the thorax and abdomen.

2. Examine a spiracle and a tube (*trachea*) leading from it with the low power of a microscope.

Conclusion. — Describe the breathing organs of an insect.

Drawing. — Side view of an insect with its parts named.

b. The Butterfly or Moth (a Scale-winged Insect)

1. General Study

Observations. — 1. How many body regions are there?

2. How many pairs of legs? Of wings?

Conclusion. — Compare the number of body regions, legs, and wings with those of the grasshopper.

Observation. — Examine a bit of wing under the low power of a microscope, and note the scales which cover the wings. How are these scales arranged?

Conclusion. — What would happen to the appearance and color of the wings if the scales were rubbed off?

Observation. — Find the mouth parts. (Use a hand lens or a chart.)

Conclusions. — 1. Are they adapted for sucking or biting?

2. Write a sentence giving the likenesses between a butterfly and a grasshopper.

3. Write a sentence giving the differences between a butterfly and a grasshopper.

2. Metamorphosis

I. The Eggs (Optional)

Observations. — 1. Note where and when the eggs of a captive moth are laid.

2. What are the size and color of the eggs?

3. How are the eggs arranged?

Conclusions. — 1. What does an egg produce when it is hatched?

2. Why are the eggs laid in certain locations?

II. The Larva (Caterpillar)

Observations. — 1. How many pairs of legs are there?

2. Note that, besides true segmented legs, there are others, called prop legs. How many pairs of prop legs are there?

3. Find the spiracles. How many are there?

4. Examine the mouth parts. Look for black objects.

Conclusions. — 1. How can you tell how much of the body is thorax?

2. Has an earthworm a thorax?

3. How can you tell a larva from a worm?

4. Are the mouth parts apparently adapted for biting or for sucking?

Note.—This is decidedly the eating stage of an insect, and therefore the stage when it does the most damage.

III. Pupa or Chrysalis Stage

Note. —Some insects construct a case or cocoon for this stage.

Observations. — 1. To what is the cocoon or chrysalis attached?

2. How is it fastened in place?

3. Of what is it composed?

4. What is inside the cover (if a cocoon)?

Conclusions. — 1. What made the cocoon?

2. What is its use?

3. What is the pupa stage of an insect?

Observations. — 1. Study a pupa which has been removed from its cocoon.

2. Are the regions of the body distinct?

3. Identify by the markings on the shell, the wings, legs, antennæ, and spiracles.

4. Is a live pupa provided with any means of locomotion?

Conclusions. — 1. Into what does a pupa develop?

2. Is this stage commonly an active or quiescent one? What seems to be its purpose?

IV. The Imago or Adult

Observations. — 1. Are there three distinct regions?

2. How does the adult stage differ from the pupa stage?

Conclusions. — 1. What is the main function of this stage?

2. Tell of the changes (*metamorphoses*) in the life history of a moth or a butterfly.

c. The Typhoid Fly (a Two-winged Insect)

Observations. — 1. How many body regions are there? Name them.

2. How many pairs of legs? Of wings?

Note. — Two-winged insects form a group known as the *Order Diptera.*

3. Are the mouth parts adapted for sucking or biting?

Conclusion. — How do these parts compare with the similar parts of other insects so far studied?

d. A Beetle (a Sheath-winged Insect)

Note. — Pupils may well here study the following insects independently of the written observations, using the summary **h**, or their own questions.

Observations. —1. Identify and name the body regions.

2. How many pairs of wings?

3. How do the fore wings differ from the hind wings? *Note.* — When the fore wings are sheathlike, evidently for protection, such insects are known as sheath-winged insects, or members of the *Order Coleoptera.*

Conclusion. — Define the order Coleoptera. What are the mouth parts fitted for.

e. The "Electric Light" Bug (a Half-winged Insect)

Observations. — 1. Note the body regions and the pairs of legs.

2. How do the fore wings differ from any so far studied?

3. Study the mouth parts.

Conclusions. — 1. *Note.* — Insects having fore wings, half hard and half membranous, are said to be "half-winged" insects, and are members of the *Order Hemiptera.*

2. For what are the mouth parts fitted?

f. The Dragon Fly (a Nerve-winged Insect)

Observations. — 1. Identify the body regions and the number of parts of legs.

2. How do the fore wings differ from any so far studied?

3. Study the mouth parts.

Conclusions. — 1. For what are the mouth parts fitted?

2. *Note.* — Insects having the wings with a network of evident nerves are said to be "nerve-winged" insects, and are said to belong to the *Order Neuroptera.*

g. The Bee (a Membrane-winged Insect)

Observation. — Follow the directions under **f.** Insects, such as bees and ants, having two pairs of membranous wings are known as membrane-winged insects, and belong to the *Order Hymenoptera.*

h. Summary of Differences between Orders

Make a table of differences among the seven orders of insects studied, using a form similar to the following: —

Orders							
Examples							
Wings							
Mouth parts							
Other points							

Conclusion. — What are some of the means of distinguishing the orders of insects from one another?

i. Making a Logical Definition

Observations. — 1. Make a table of resemblances of the preceding seven orders of Insects, using the following form: —

Insects	Eyes	Wings	Legs	Appendages	Body Regions	Breathe How
Grasshopper						
Butterfly, or Moth						
Fly						
Beetle						
Squash Bug						
Dragon Fly						
Bee						

2. What characters in the above table fit *all* the insects studied? Write them out into a definition of an insect (class *Insecta*).

Note. — Orders which are alike form a class. While our definition just formed is not complete, yet it illustrates how logical definitions are made.

Conclusions. — 1. What is an insect? *Note.* — There are some 400,000 kinds of insects already known.[1] Each kind, as of grasshoppers, is called a *species.* So a species is made up of individuals that are very much alike. Species that are very much alike form a *genus.* Genera that are much alike constitute a *family* and families much alike constitute an *order*, as the *Order Orthoptera.* As with a man, every animal and plant is given two names. Thus the typhoid fly is named *Musca domestica*, which is a combination of the generic name first, followed by the specific name, much as a man's

[1] More than all other known kinds of animals taken together.

name might be written in a directory as Jones, John, the group name coming first, and the special name last. Further, *Orders* make *Classes*, *Classes* make *Branches* or *Phyla*, and Branches make *Kingdoms*, as the Animal Kingdom or Plant Kingdom. Thus we might tabulate the typhoid fly as follows:—

Kingdom, Animal.
  Branch, Arthropoda or joint-legged animals.
    Class, Insecta.
      Order, Diptera.
        Family, Muscidæ.
          Genus, Musca.
            Species, domestica.

j. Field Work (Optional)

Observations. — Collect as many different kinds of insects as you can. Bring them to the classroom or to your home. Sort them into the different orders, placing each order in a separate box. Try using the following identification table, or synopsis.

Identification Table of some Classes and Orders of Arthropoda

A. With three pairs of legs.
  B. With jawlike mouth parts, for biting.
    C. The two pairs of wings unlike in structure.
      D. Fore wings meeting in a straight line, hard and "sheath-winged"; hind wings crumpled. Coleoptera (sheath-winged).
      DD. Fore wings leathery and commonly meeting in a straight *ridge*; hind wings folding lengthwise like a fan. Orthoptera (straight-winged).
    CC. The two pairs of wings alike in structure.
      D. With many "nerves" in the wings. No sting. Neuroptera (nerve-winged).
      DD. With few "nerves" in the wings. With a sting. Hymenoptera (membrane-winged).
  BB. Mouth parts tubelike, for sucking.
    C. Two pairs of wings.
      D. Wings covered with powdery scales. Lepidoptera (scale-winged).

DD. Fore wings half hard and half soft. Hemiptera ('half'-winged.)

CC. One pair of wings. . . . . . . Diptera (two-winged).

AA. With four pairs of legs, no wings, and two body regions. Arachnida. (Spiders.)

AAA. With many pairs of legs. No special body regions. No wings. Myriapoda. (Centipedes, etc., Hundred-legged.)

Questions

1. Name the seven principal orders of insects, and give an example of each.
2. What are the characteristics of the lepidoptera?
3. How distinguish a fly from a bee?
4. What are the insecta?
5. How distinguish a spider from an insect?
6. How distinguish myriapods from spiders?
7. How do you get a *logical* definition of the class insecta?
8. How tell a bug from a beetle?
9. When are caterpillars the most abundant?
10. At what stage does a moth do the most damage?
11. What constitutes a scientific name?

Special Topics

1. Classification of insects.
2. Metamorphosis of insects.
3. Economic importance of the locust.
4. Comparison of activities of crayfish and grasshopper.

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PROBLEM XXXI

How insects became winners in life's race. (Shifts for a living.)[1]

a. Protective Resemblance

Observations. — 1. Examine a green katydid on a green-leaved twig. Is it easy to distinguish it from the leaves?

2. Examine a "walking stick" on a twig. Is it easy to tell it from the twig?

3. Note a kallima or "dead leaf" butterfly on a twig. What does it resemble?

Conclusions. — 1. Of what advantage is it to the katydid that it resembles the green leaf?

[1] This problem may be made the basis of a museum trip.

2. Explain any advantages apparent in the cases of the "walking stick" and the kallima.

Note. — When an animal's color, shape, and markings cause it to harmonize with its usual surroundings, it is said to be a case of general *protective resemblance.* What is the difference between mimicry and protective resemblance?

b. Aggressive Resemblance

Observations. — 1. Notice the terrifying attitude of a tomato worm larva. In what way does it terrify?

2. Many insects, when disturbed, lift the hind part of the body or threaten to sting, although they have no sting.

Conclusion. — Of what advantage is it that some insects assume terrifying attitudes? *Note.* — Animals that adopt a terrifying or fighting attitude are said to be examples of *aggressive resemblance.*

c. Mimicry

Observations. — 1. Study the example of the inedible monarch and the edible viceroy. Which one mimics the other?

2. Compare a flower fly with a honeybee. What do you observe?

Conclusions. — 1. What advantages to the butterfly that mimics the other?

2. How might a flower fly be protected from its enemies?

3. Do you think an insect *intends* to resemble another one. If not, then how might this state of affairs come about?

d. Communal Life

Observations. — 1. Explain the community life of the honeybee. How many different kinds of individuals in a colony?

2. Give other examples of animals leading a communal life.

Conclusions. — 1. Of what advantage is communal or society life to an animal?

2. Show whether or not there is division of labor here.

e. Commensalism or Symbiosis

Observations. — 1. Study the case of the sea anemone with many stinging cells, on the shell of a hermit crab. Just where is the sea anemone located?

2. Note that sponges may also be found on the backs of some crabs.

Conclusions. — 1. What advantage is the presence of the sea anemone to the crab?

2. What are the advantages to the sea anemone because of being on the back of the crab? *Note.* — Where animals of different sorts associate themselves for mutual benefit, it is said to be a case of *commensalism* or *symbiosis*.

f. Parasitism

Observation. — Many insects are parasitic as we have seen some worms to be. How do the sucking lice get their living?

Conclusions. — 1. Are there any advantages to an animal that adopts a parasitic life? What disadvantages?

2. Give other examples of parasites among insects.

Questions

1. What is "protective resemblance"? Give three examples you have studied.
2. What is the meaning of the term "metamorphosis"?
3. Give an account of grasshopper migrations and plagues.
4. Could you drown a grasshopper by holding its head under water?
5. What is meant by the 'economic importance' of an insect?
6. What sort of metamorphosis has a locust?
7. When is the best time to collect cocoons?
8. How may insects "shift for a living"?
9. What is the meaning of the following: —

"So work the honeybees:
Creatures, that by a rule in nature, teach
The act of order to a peopled kingdom."

Special Reports

1. The utility of color to animals.
2. How insects shift for a living.
3. Ant communities.
4. Some parasitic insects and their hosts.
5. Division of labor among insects.
6. Adaptations among insects.

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Hunter, *Essentials of Biology.* Chap. XX.

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PROBLEM XXXII

Some relations of insects to man.

a. With Reference to Disease

1. The Typhoid Fly

Note. — House flies are charged with carrying germs of typhoid fever, dysentery, tuberculosis, and diarrhea.

Observations. — 1. The female of the common house fly lays her eggs in manure or any dooryard filth. They hatch in about one day and the larvæ appear like small worms. These

grow for about one week, then pupate for another week, when they emerge as adults. How long is their life history?

2. Flies also breed in excrement of any sort. Suppose this excrement should come from those suffering from bacterial diseases, and the flies breeding therein should travel directly to foods. What will most surely happen?

3. Study Figure 50. A fly was allowed to walk over some material (gelatine) that is food for bacteria. Each white spot shows where a germ was left, and a colony has grown from it. Where did the fly probably obtain the bacteria?

Fig. 50. — Bacteria left by fly passing over gelatine plate. (Courtesy of The Merchants' Association of New York.)

Conclusions. — 1. What must surely happen if flies are permitted to crawl over our food, or on our hands and faces?

2. How may typhoid and other diarrheal diseases be spread about?

Observation. — Refer to Figure 51.

Conclusions. — 1. Write a paragraph concerning the dangers of open spittoons, or of spitting in public places. Remedies?

2. Tell of the dangers of any open garbage pails, or toilet closets, or any exposed decomposing vegetable or animal matter.

3. Why should fruit dealers and others selling food of any description see that their goods are protected from flies and street dust?

4. Why should the doors and windows of dining rooms and kitchens especially be screened?

5. Why should you talk with your neighbor about the fly nuisance?

6. Why should extra precautions be taken to keep flies away from those suffering from contagious diseases?

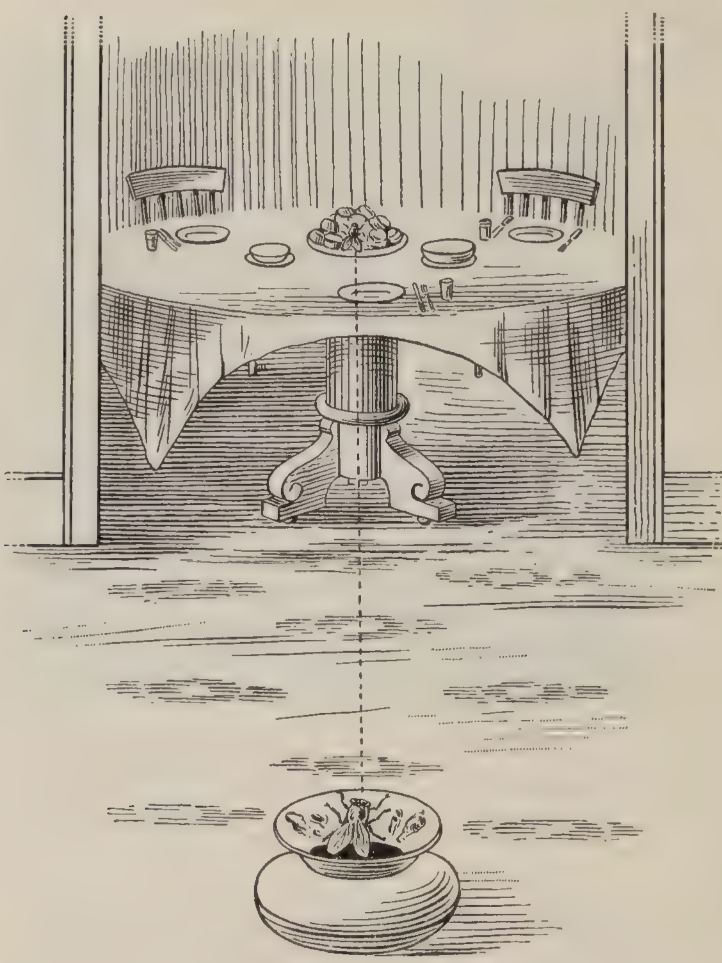

FIG. 51. — Showing why open spittoons should not be used by any one — especially by diseased persons.

7. How may bacteria enter the bodies of children?

8. What objections to the ordinary way of sweeping?

9. Why should garbage cans be sprinkled with kerosene or lime?

10. Write a paragraph on the necessity of street and home cleanliness.

Home Work. — 1. Catch a few flies and place them under an inverted gallon jar, or catch a number in an ordinary wire trap. Place a small amount of pyrethrum powder in a small paper funnel, ignite it, and place in the jar or cage. Result?

2. Heat a few drops of carbolic acid on a shovel in a room where there are flies. Result?

Conclusion. — Why should pyrethrum powder be burned in the home at times, — especially in the kitchen and dining room? What is the effect of carbolic acid vapor?

Questions

1. What name is given to the young of flies? Where may they be found?

2. How long does it take to develop a generation of flies?

3. During what part of the year are house flies the most abundant?

4. Explain the statement, "Flies were more deadly than Spanish bullets."

5. What diseases may be carried by flies?

6. What is the relation between temperature and the typhoid rate, where the water supply and general sanitation is good? Where poor?

Special Reports

1. The habits and breeding places of the typhoid fly.
2. Typhoid fever and the fly.
3. The house fly as a carrier of disease.
4. How insects affect the health in rural districts.
5. Flies as spreaders of disease in camps.
6. Means of destroying typhoid flies.

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2. The Mosquito

(*a*) *The Egg*

Observation. — Look for the eggs of the mosquito, any time in warm weather (April to October), on the surface of stagnant pools. Look for them wherever the common wigglers are to be found. *Note.* — The eggs are laid in small rafts or packets, or singly, in the case of *anopheles,* the malarial mosquito. They float on the surface of the water.

Conclusion. — How are the eggs adapted to their habitat?

(*b*) *The Larvæ* (*Wigglers*)

Observations. — 1. Put some wigglers in a small bottle of water. What is their shape?

2. How do the larvæ reach the top of the water? How reach the bottom?

3. Watch the larvæ while at the surface. Which end is up? Does the end (respiration tubes) reach through to the air?

4. What is the position of the larvæ while at the surface? *Note.* — If they lie horizontal to the surface, they are the larvæ of the anopheles, the malarial mosquito.

Conclusions. — 1. Explain why the larvæ often come to the surface.

2. How tell the larvæ of the malarial mosquito from the ordinary mosquito?

Observation. — Place some of the larvæ in an aquarium with a small native fish, — as a sun fish, perch, bass, or shiner. A goldfish will serve. Does the fish eat the larvæ? If so, how many does it eat at a meal?

Conclusion. — Explain one way of ridding a pond of mosquito larvæ.

(*c*) *Pupa*

Observations. — 1. Place a number of larvæ in another aquarium. Place a screen over the aquarium, and observe from time to time to see them molt their skins. How does the pupa stage differ from the larva stage?

2. Look for empty pupa shells floating in the water. Where do they split open? What came from them?

3. Place a few drops of kerosene on the surface of the water. What happens to the larvæ and the pupæ? What happens to any winged forms?

Conclusions. — 1. Explain another way of ridding ponds of mosquito larvæ and pupæ.

2. What two ways of destroying larvæ and pupæ do you now know? Which one is nature's method?

3. Which method do you think is the cheaper and most reliable? Explain.

Observations. (*A field trip.*) — 1. Plot a map of a district, showing all the ponds and streams containing mosquito larvæ, also those containing none.

2. Are mosquito larvæ more abundant some places than others? If so, where?

3. Are there fish where no mosquito larvæ or pupæ are found? Are there toads or frogs? Are there other animals?

Conclusions. — 1. How can you account for the lack of wigglers in some of the ponds or streams?

2. How could you free some of the other places of wigglers? (Try any experiments you can.) *Note.* — All ponds too filthy or temporary to stock with fish or tadpoles should be drained, or at least covered with a film of kerosene. Use about one ounce of oil to 15 sq. ft. of surface.

(*d*) *The Adult*

Observations. — 1. How many pairs of wings? Of legs? Body regions?

2. Find the antennæ. *Note.* — The antennæ of the males are more bushy than those of the females.

3. What is the resting position of the adult?

Conclusions. — 1. Does the mosquito pass through a metamorphosis? Explain.

2. How tell an adult anopheles or malarial mosquito from the common mosquito or culex?

(*e*) *Relation to Man*

Observations. — 1. What is malaria? Why is malaria commonly associated with low lands, swamps, and stagnant waters?

2. Might there be any connection between the number of mosquitoes of any region and the number of cases of malaria? *Note.* — Malaria and yellow fever are now known to be carried by mosquitoes. These diseases are caused by small organisms that are in the blood of the infected, or sick.

Conclusions. — 1. Suppose a person suffering from malaria is bitten by a certain sort of mosquito (anopheles). What would likely be found afterwards on the mouth parts of the mosquito?

2. Suppose this mosquito should now bite another person. What would most certainly happen?

Observations. — 1. The anopheles mosquito seems to be standing on its head when at rest, while the ordinary mosquito rests about as a house fly does. Can you find any malarial mosquitoes?

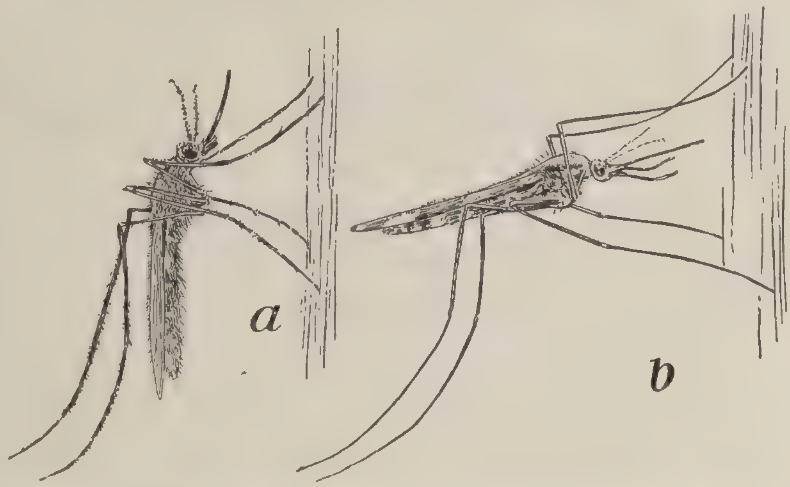

FIG. 52. — Mosquitoes. *a*, position taken by a common mosquito (culex) when alighting; *b*, position taken by a malarial mosquito (anopheles) when alighting.

2. Try feeding mosquitoes to toads. Do they eat them? What birds also eat mosquitoes?

Conclusion. — Write a paragraph telling all the ways known to you for preventing malaria and yellow fever.

Questions

1. How tell a malarial mosquito from the common sort (culex)?
2. Describe the metamorphosis of the mosquito.
3. What diseases are charged to the mosquito?
4. How may these diseases be fought?

Special Reports

1. Mosquitoes and malaria.
2. Yellow fever and mosquitoes (stegomyia).
3. Means of destroying mosquitoes.
4. Extermination of mosquitoes.
5. Animals that eat mosquitoes.

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b. With Reference to Property Destruction [1]

1. Gardens

Observation. — Prepare a special report on one of the following insects: —

Squash bug, tomato worm, cabbage butterfly, potato bug, aphids.

Tell just how they are harmful and how to fight them.

2. Crops

Observation. — Prepare a report as above on one of the following insects: —

Chinch bug, weevil, army worm, cutworm, cotton-boll weevil.

3. Orchards

Observation. — Select one of the following for a special report as above: —

San José scale, codling moth, apple tree tent caterpillar.

[1] Refer to the Bulletins of Agricultural Experiment Stations and of the U. S. Department of Agriculture. Many of these may be had free on application.

4. Forest

Observation. — Select one of the following as above: —

Weevil, forest tent caterpillar, tussock moth, maple tree scale, fall webworm, elm leaf beetle.

5. House Pests

Observation. — Select one of the following as above: —

Roaches, bedbugs, clothes moths, carpet beetles, flies.

c. With Reference to Benefit to Man

Observation. — Write a report on your choice of one of the following topics: —

Honeybee, ichneumon fly, silkworm, ladybug, tachina fly, ink galls, blister beetles in medicine, lac insect, cochineal, bumblebee, carrion beetle.

Note. — The above topics may well be given out through choice of the pupil or else assigned to different members of the class, if it is desirable that all the topics be taken up.

d. Summary

Beneficial					Harmful				
Name	Larva	Pupa	Adult	Benefit	Name	Larva	Pupa	Adult	Harm

Fill in the above table.

Questions

1. What does your state do in destroying insect pests?
2. Name thirteen six-legged villains.
3. What does the United States government do in destroying insect pests?

4. Name some insects that make trouble for the housekeeper.

5. Name some insects that injure the foliage.

6. What damage is annually done the wheat crop by the chinch bug?

7. Name some insects that make trouble for the farmer.

8. Name five different ways that insects are useful to man, with an example of each.

9. Name some insects that make trouble for the horticulturist.

10. Name five different ways insects are harmful to man, with examples of each.

11. What damage is annually done by the locust in time of plague? By the Hessian fly?

12. What are the chief enemies of insects that hinder their becoming a plague?

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THE BIOLOGICAL RELATIONS OF SOME AQUATIC FORMS OF LIFE

PROBLEM XXXIII (Optional)

A study of mollusks and their enemies with special reference to their economic importance.

a. Relations

Observations. — 1. Fill in the following tabulation : —

Names	Habitat	Enemies	Economic Importance	Value
Oyster . . .				
Clam . . .				
Mussel . . .				
Scallop . . .				
Snails . . .				
Oyster Drill .				
"Shipworm".				
Squid or Cuttle-fish . . .				

Questions

1. Why are stakes and brush sometimes sunk in shallow water in artificial oyster culture ?
2. What is the source of sepia ?
3. Where are the best pearl fisheries ?
4. Where is the center of the pearl button industry in this country ?

Special Reports

1. The use of shells as money.
2. The artificial pearl industry.
3. The starfish in relation to mollusks.

4. The pearl button industry.
5. Mollusks as food.
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7. Oyster culture.

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PROBLEM XXXIV

A study of how a live fish is fitted for the life it leads.

Materials. — Small battery jars with living fish of small size, such as goldfish or bream.

a. Adaptations for Locomotion

Observations. — 1. Note the general divisions of the body into head, trunk, and tail. Is there a neck?

2. Watch the fish carefully and see how it moves.

3. How many paddle-like structures (*fins*) are there?

4. How many fins are in pairs?

5. *Note.* — Any fins on the dorsal side of the body are called *dorsal fins.* The fin on the tail is called the *caudal fin*, and the median fin on the ventral side is the *anal fin.* The anterior paired fins near the head are called *pectoral fins*, while those about midway and ventrally located are called the *pelvic fins.*

Conclusions. — 1. How does a fish move forward?

2. What are the uses of the caudal fin?

3. What are the particular uses of the pelvic fins?

4. What adaptations that you have studied fit a fish for life in water? Explain.

5. Tell just *how* any one fin or set of fins is adapted or fitted to do its work.

b. Adaptations for Respiration

Observations. — 1. What movements of the mouth do you observe?

Note. — As the fish closes its mouth, note the movements of the *operculum*, or bony flaps just in front of the slits on the side of the "neck" region.

2. Does the operculum open or close as the fish closes its mouth?

3. Do you see red gills underneath the operculum?

4. Pour water from a height into the battery jar or aquarium. What is carried into the water?

Conclusions. — 1. How can you temporarily aerate an aquarium?

2. How could a fish be suffocated without taking it out of water?

3. What precautions should be observed in keeping fish in aquaria?

4. Mention at least two respects in which fishes are adapted to lead an aquatic life.

5. Why should the operculum open as the mouth closes?

6. Tell just how a fish breathes.

7. Why should a fish breathe?

c. Sense Organs

Observations. — 1. What movements of the eyes do you notice?

2. How large a range of vision has it (number of degrees)?

3. Can a fish close its eyes?

4. *Note.* — Look at the skeleton of a fish, and note the deep cavity (*orbit*) in which the eyes are set.

Conclusions. — 1. Do you conclude that its sight is keen?

2. How does its range of vision compare with that of man?

3. Why should a fish have sensory (sense) organs?

d. External Adaptations

Note. — Use preserved specimens.

Observations. — 1. With what is the body covered?

2. What is the general arrangement of the covering? *Note.* — The scales and horny rayed fins constitute what *exoskeleton* there is present. Is there another skeleton? If so, where?

Conclusions. — 1. How is the exoskeleton of scales adapted to protect the fish?

2. How is the sliminess or slippery character of the scales of advantage?

3. How are the scales adapted to gain flexibility of the body?

Drawing (*Optional*). — Sketch a side view of a fish. Label: head, eyes, dorsal fin, pectoral fin, anal fin, caudal fin, and gill cover.

e. Internal Adaptations (Optional)

1. Skeleton

Note. — Use prepared skeleton or a chart.

Observations. — 1. Notice a column of bones (the *vertebral column*, or backbone) running the full length of the fish. Is it solid or flexible?

2. Where are the ribs attached?

Conclusions. — 1. Since this skeleton is inside the body, it is called an *endoskeleton*. What do you think is its general purpose?

2. Of what advantage that it be constructed of so many parts, rather than a rigidly formed framework of few parts?

3. Why should fishes have internal skeletons?

4. What is meant by the term "adaptation of structure to function"?

5. In what different ways does the skeleton of a fish show adaptations of structure to functions?

2. Internal Organs

Note. — Use preserved specimens with ventral body wall cut away.

Observations. — 1. Push a slender probe down the throat, into the

esophagus, which leads to an enlargement called the stomach. What is the shape of the stomach?

2. Note that the stomach leads to the *small intestine*. This in turn leads to the *large intestine*. How does the small intestine compare in length with the stomach?

Conclusion. — Why should a fish be provided with digestive organs?

Questions

1. Mention ten important food fishes found in the market.
2. Where and how were these caught? (Ask the fish dealer.)
3. Mention some of the peculiar breeding habits of the salmon and the shad.
4. Mention five important food fishes found in fresh water. How and where were they caught?
5. What is a game fish?
6. Where are some of the most important game fishes caught?
7. What is the United States Fish Commission, and what does it do?
8. What is a fish warden?
9. What is a closed season? Why necessary?
10. What is caviar? Why is its sale causing the practical extinction of a certain sort of fish?
11. Mention as many commercial products as you can, derived from fishes.
12. What is the food of young fish?
13. Why is a fish called a vertebrate?
14. Where are your state fish hatcheries located?
15. What fishes are propagated in your state?
16. Is the whale a fish? Explain.
17. What is a balanced aquarium?
18. What did Dryden mean by the following statement?

> "Thus fishes first to shipping did impart,
> Their tail the rudder, and their head the prow."

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PROBLEM XXXV (Optional)

A study of some of the relations of fishes to their food supply.

a. Land Plants

Observations. — 1. What have we learned may be in solution in soil water?

2. Name some plants that get their mineral matter from the soil.

3. What else have we learned plants use as food matter?

4. What are plants able to do with the raw materials they obtain from the air, with the aid of chlorophyll and sunlight? What is the name of this process?

Conclusions. — 1. What food materials may be furnished animals by plants?

2. What changes in the composition of the air brought about by photosynthesis in plants?

b. Water Plants

Observations. — 1. Are the salts found in soil water also likely to be found in the waters of ponds, rivers, and oceans?

2. If water plants and algæ also contain chlorophyll, what is the result in sunlight?

Conclusions. — 1. Many snails eat fresh-water plants, while they in turn are eaten by many fishes. What relationship, then, do water plants bear to man?

2. Many aquatic insect larvæ eat fresh-water plants, and are in turn eaten by many small fish and crayfish. How are aquatic insects related to water plants, on the one hand, and small fishes, on the other hand?

3. Larger fishes, as the bass, pickerel, and pike, eat smaller fishes and crayfishes, and are in turn eaten by man. Trace the importance of water plants to man.

Observation. — If possible, collect some mosquito larvæ (wigglers). Put them in a small aquarium, with a small perch or sunfish. A goldfish will serve. Does the fish eat them?

Conclusion. — Ordinary mosquitoes eat small organisms near the surface, while other mosquito-like insects (chironomus) eat decaying plant material on the bottom. Trace the possible relationship of decaying plant material of ponds, etc., to man.

Observations. — 1. Many small algæ are eaten by small crustaceans (entomostraca). These furnish food for the young of many fishes, as lake herring, which in turn furnish food for lake trout.

2. Many algæ and Protozoa are eaten by small mollusks (snails, mussels, and clams) and these in turn by the whitefish, etc.

Conclusion. — Of what importance are algæ and Protozoa to man? Explain how you get your conclusion.

Observations. — 1. Many algæ (as *diatoms*) are eaten by entomostracans, these by the sprat, the sprat by the whiting, the whiting by the cod, and the cod by man.

2. Many algæ are eaten by Protozoa and other small forms, these by worms, the worms by crabs, the crabs by the cod, and the cod by man.

Conclusion. — Explain desirable conditions for producing cod for food purposes on a large scale.

Observations. — 1. Many algæ are eaten by Entomostraca (copepods, etc.), these by the herring, the herring by the mackerel, the mackerel by man. Just what food is furnished the Entomostraca by the algæ?

2. Out of what raw materials do the algæ manufacture this food? Only when can chlorophyll manufacture it?

Conclusions. — 1. What then is the relationship of weather conditions to man's possible supply of mackerel? Trace the steps in your reasoning.

2. Explain the statement, "Our living food from the waters of the globe may be said to be the diatoms (algæ) and other microscopic organisms."

3. Interpret the expression, "Plants are producers and animals are consumers," using any example above.

4. Justify the following sentence, "The pastures of the sea" are no less real and no less necessary, than those of the land.

Observations.—1. Are rooted aquatic plants the most abundant in pools or ponds with clay or loamy bottoms? Why?

2. Are aquatic plants of any advantage to animal life present? Explain.

Conclusions.—1. What sort of a bottom is best for a pond you wish to stock with fish? Explain.

2. The Great Lakes have little shore area with rooted aquatic plants. Would this probably influence the number of small animals there?

3. Show how the lack of aquatic plants and animals could likely influence the fish life there.

Questions

1. What is meant by the term "aquiculture"? "Agriculture"?

2. What is the meaning of the term "ecology"?

3. Why should a body of water be studied with reference to the ecology of the life there, before stocking it with fish?

4. What is plankton? Why is its study important?

5. What is the meaning of the term "microcosm"? Explain how a small pond might be so termed.

6. What are the reasons for the establishment of the United States Fish Commission?

7. Just what is meant by Thompson in the following?

> "Full nature swarms with life: one wondrous mass
> Of animals and atoms organized. Where the pool
> Stands mantled o'er with green, invisible
> Amid the floating verdure millions stray."

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PROBLEM XXXVI (Optional)

The artificial propagation of fishes.

Observations. — 1. Schools in the neighborhood of state or government fish hatcheries[1] may well visit them and watch the artificial methods of raising fishes. If possible watch the "stripping" of the females for roe (eggs) and the males for milt (sperm). Which is the larger, roe or milt? Which is the more active? Why?

2. Note that the roe is squeezed out into a moist bucket, and the milt is immediately poured over it and the eggs gently stirred about. Why?

3. Several changes of water are now poured over the eggs and they are then set aside to develop.

Conclusions. — 1. What is meant by the term "artificial fertilization"?

[1] In lieu of such hatcheries, study Figures of the process, for salmon or trout. See a Manual of Fish Culture, Department of U. S. Fish Commission for 1898, Plates 16, 28, 34, 53, especially for salmon and trout.

2. Of what value is artificial propagation?

3. Is such fertilization external or internal? *Note.* — Female fishes are in the habit of laying their eggs on the bottom in various localities, and the male afterwards sprays them with milt.

4. Write an account of the process of artificial fertilization in fishes.

Questions

1. What is meant by the term "fertilization"?
2. What fishes are commonly artificially propagated? Why?

Special Reports

1. Fish culture.
2. The transportation of fish and fish eggs.
3. Spawning season.
4. The salmons.
5. The trouts.
6. The United States Bureau of Fisheries.

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THE STUDY OF THE FROG AS AN INTRODUCTION TO MAN

PROBLEM XXXVII

Some adaptations in a living frog, as an introduction to the study of man.

Material. — Live frogs, battery jars, charts.

a. External Bodily Adaptations

Observations. — 1. How does the shape of the frog differ from that of the fish?

2. What is the general color of the frog? What markings are there?

3. Is the skin rough or smooth?

Conclusions. — 1. In what sort of surroundings would the general color and markings of the frog tend to conceal it?

2. Has the frog an exoskeleton?

b. Adaptations of Appendages for Habitat

Observations. — 1. How many appendages are there? What are they?

2. What is the greatest difference between the fore and hind legs?

3. What is the resting position of the hind legs?

4. How do the feet differ? *Note.* — The thin membranes between the toes of the hind feet are called *webs.*

5. Describe the web of one of the feet.

6. Cause the frog to swim. Which legs are of the most service in swimming? In hopping?

7. Can a frog stand?

Conclusions. — 1. What in the frog corresponds to the pectoral fins in the fish? To the pelvic fins?

2. How is the resting position of the hind legs of especial advantage?

3. How are the hind legs fitted for swimming?

4. Would it be well for a person to pattern after a frog in learning to swim? Explain.

5. Tell how the hind legs are especially fitted (adapted) for jumping.

6. Tell how a frog is adapted for life on land. For life in water.

c. Adaptations for Food Getting

Observations. — 1. Touch various parts of a frog gently with a splint or pencil. How does it respond?

2. Compare the external position and shape of a frog's eye with that of the fish you studied. Is the eye more movable? Is it better protected?

3. Just back of the eye find a large drumlike organ (*ear drum*). Describe it.

Conclusions. — 1. What portions of the body appear to be the most sensitive?

2. Can you suggest any reasons for the differences between a frog's eyes and those of a fish?

3. What do you decide is a frog's range of vision?

4. Why does a frog need sense organs?

d. Adaptations for Respiration

Observations. — 1. Watch carefully for any movements of the throat, nostrils, and sides of the body. What do you see?

2. Does the frog open its mouth while breathing? Do the nostrils open and close? If so, is there a throat movement at the same time?

Conclusions. — 1. Does the throat movement that takes place when the nostrils close increase or decrease the size of the mouth cavity? Where, then, must the air be forced?

2. Study a diagram of the respiratory organ of the frog, and write a paragraph telling just how a frog gets air into and out of its lungs.

Observations. — 1. Does the frog always remain entirely under water? If not, what part of its head does it place out of water? Why?

2. Examine a dissected specimen or chart, showing *bronchial tube*, *trachea*, and *glottis*. Insert a blowpipe in the glottis and inflate the lungs. Are they spongy? Are they elastic?

Drawings (Optional)

Draw a side view of the living frog, natural position. Label all parts mentioned in the previous study.

Questions

1. What is the meaning of the term "Amphibia"?
2. Give the principal ways Amphibia may be useful to man.
3. What becomes of frogs and toads in the winter?
4. Tell of metamorphism amongst the Amphibia.
5. Why has the frog been used so much for dissection?
6. How does the food of larval and adult frogs differ? How do their digestive organs differ?
7. What are the principal enemies of frogs?
8. What is the truth about toads and warts?
9. Why should the toad be reckoned a good citizen?
10. How are the eggs of frogs protected from ravenous fishes?

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PROBLEM XXXVIII

A study of the development of the frog (metamorphosis).[1]

Collecting

Observations. — 1. Look for frogs' eggs in fresh-water ponds late in March or early in April. To what do you find them attached?

2. Collect some in a pail of water and bring them to the laboratory or recitation room. Place them in a shallow aquarium with some algæ or other water plants, and keep it supplied with water as needed.

Conclusion. — Where and when do frogs lay their eggs?

a. Conditions Favorable to Development

1. Temperature

Observation. — Place some eggs in shallow dishes, as saucers. Place one lot in a moderately warm room, another lot in a cold room, and a third lot on cracked ice. Observe often for about ten days and record results.

Conclusion. — What is the relation of temperature to the development of frogs' eggs?

2. Oxygen

Observation. — Place a *large number* of eggs in a saucer of water. Place a *few* eggs from the same batch in the same

[1] Toads' eggs may be used with the advantage of being laid later in the season.

amount of water. Place where they receive the same amount of light and moderate heat. Observe them daily for about ten days.

Conclusions. — 1. Which lot receives the most oxygen per egg? Explain.

2. What is the effect of oxygen on the development of frogs' eggs?

3. Water

Observation. — Place a few eggs in a saucer of water, and an equal number from the same lot in another saucer with but water enough to keep them moist. Take care that they do not dry up. Place them where there are equal amounts of light and moderate heat. Observe daily for about 10 days. Which lot develops the better?

Conclusion. — What is the effect of moisture on the development of frogs' eggs?

4. Fertilization

Observation. — The eggs when collected from the pond have probably already been fertilized. The eggs were laid in the water by the female and the males at once shed or sprayed sperm cells or *milt* over them, thus fertilizing them. *Note.* — A thin albuminous coating immediately swells up, and they stick together to form a mass in the water. If a number of hens' eggs should be broken into some water, a mass similar to frogs' spawn or eggs would be the result — the yolks corresponding to the frogs' eggs.

Conclusions. — 1. What may be the use of the gelatinous mass?

2. Sum up the conditions necessary for the development of frogs' eggs.

b. General Development (Metamorphosis)

Observations. — 1. With models review the development of an egg to the gastrula stage. *Note.* — By the tenth day a

fertilized frog's egg will begin to show head, body, and tail. Small gills grow from the neck region, and in about two weeks the young tadpole emerges and swims about.

2. Where do the tadpoles arrange themselves in the aquarium? Of course you see to it that they are in a balanced aquarium as near as possible, and no fish therein. Why?

Conclusions. — 1. How do young tadpoles breathe?

2. Upon what do they feed?

Observations. — 1. Trace the development of a young tadpole, either by studying specimens of various ages, prepared mounts, and charts or figures. Do they have gills for any length of time?

2. Do the tadpoles ever come to the surface?

Conclusions. — 1. Do tadpoles need a tail? Explain.

2. In what two different ways do tadpoles breathe?

Observations. — 1. Which pair of legs develops first?

2. What soon happens to the tail?

3. Does the mouth remain the same? Can you find teeth in a frog's mouth?

Conclusions. — 1. When is a tadpole's tail no longer needed?

2. How does an adult frog differ from a tadpole, — breathing, locomotion, food, etc.?

3. Write a paragraph tracing the different stages in the development of a frog.

c. The Toad (Optional)

Observations. — 1. Look in ponds in early May for eggs much like frogs' eggs, but in strings instead of masses. Bring to the laboratory and watch their development. If possible catch some toads and place them in an aquarium. Watch for the laying of eggs.

2. See that some of the females are separated from the males. Watch to see if they lay eggs. If so, place some of them in a shallow aquarium, as in directions under **a**. Do they develop? If not, explain.

Questions

1. Explain the story, "Toads are often rained down."
2. Of what value is the toad to man?

3. What is meant by the term "metamorphosis"?
4. What stages of a tadpole are most like a fish?
5. What becomes of frogs and toads in winter?
6. What are the Amphibia?
7. When do frogs lay eggs? Where?

Special Reports

1. Artificial fertilization of frogs' eggs.
2. The usefulness of the toad.
3. The artificial propagation of frogs.

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BIRDS IN THEIR RELATION TO MAN

PROBLEM XXXIX (Optional)

A study of some adaptations and reactions in birds.

Material. — Bird skins or mounted birds, skeleton of bird, charts, live English sparrows if possible.

a. Some Adaptations

Observations. — 1. How is a bird protected? Just how are the feathers arranged?

2. How many parts to the bill of a bird?

3. What especial shape is the bill of the bird you are studying?

4. What locomotor organs are there?

Conclusions. — 1. Mention adaptations of the feathers for flight. The shape of the body for flight.

2. Is the bill adapted for eating seeds or other food? Explain.

3. How are the wings adapted for flight?

4. Study a bird's skeleton. What adaptations for flight do you find?

5. For what are the feet adapted?

b. Some Activities

Observations. — 1. Watch a bird (English sparrow) in flight. Note the change in the position of the wings.

2. What other means of locomotion has it?

3. Watch its methods of eating or drinking.

Conclusions. — 1. Just how are the wings adapted to their particular use?

2. For what are the feet adapted? The bill?

Observation. — Observe any other activities that you can and write the conclusions you form from these observations. Try doing this at all times, so far as you can, as original work.

Drawings

Sketch a side view of head and bill. Of one foot. Label the parts and show adaptations.

Questions

1. What are the various foods of birds?
2. What is molting? Of what advantage is it?
3. Name some diving birds. Some that catch fish. Some that catch worms. Some that catch insects. Some that search the bark of trees for food. Some that scratch the earth for food, and some that eat seeds.
4. What are bird migrations? What is supposed to be the cause of bird migrations?
5. What are permanent residents? Name some. What are summer residents? Name five that nest in your city or town. Five that nest in the suburbs.
6. Who was Audubon? What is the purpose of the Audubon Association?
7. Give the laws of your state for the protection of birds.
8. What birds are not to be killed during any part of the year?
9. Name the different ways in which birds are useful to man. Are any harmful to man?
10. When and why were English sparrows introduced? Why have they increased so greatly?
11. What is the importance of ostrich farming?
12. What is the economic relation of the starling?

Special Reports

1. Birds and millinery.
2. Bird migrations.
3. The economic importance of birds.

4. The breeding of fancy pigeons and fowl.
5. The history of the passenger pigeon.
6. The work of Audubon.
7. Adaptations in bills of birds.
8. The food of some common birds.
9. Birds of city parks.
10. The introduction and spread of the starling.

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PROBLEM XL

How birds are of economic importance.

a. Food of Birds

Observations. — 1. Fill out the following tabulation on the food of some birds: —

Birds	Insects	Grains	Fruits	Rodents	Fishes	Miscell.
Gulls						
Kingfisher . .						
Owl						
Kingbird . . .						
Swallow . . .						
Cuckoo . . .						
Wren						
Phœbe . . .						
Robin						
Blackbird . .						
Thrush . . .						
Crow						
Catbird . . .						
Starling . . .						
English Sparrow						
Quail						

Note. — Dr. S. A. Forbes, State Entomologist for Illinois, believes that if the operations of birds in Illinois were stopped for a period of seven years, the entire state would be covered with insects, one to a square inch. He estimates birds' value to agriculture at $76,000,000 a year.

2. Which of the above birds are clearly beneficial? Clearly harmful? Explain your answers.

b. Special Economic Importance of Some Birds

Observations. — 1. Fill in the following tabulation: —

Uses	Names of Birds
Insect Eaters	
Game Birds	
Poultry and Eggs	
Plumes	

Uses	Names of Birds
Pillows, Mattresses, etc. . .	
Muffs, Boas, etc.	
Scavengers	
Decoration	
Other Uses	

2. Which of the above purposes are proper? Which most harmful? Explain.

c. Some Causes of Decrease in the Number of Birds

Observations. — 1. Show how the following factors interfere with the number of birds: —

Factors	Birds Affected	How the Factors Interfere
Clearing of Forests		
Draining of Swamps . . .		
Cultivation of Land . . .		
Slaughter for Game . . .		
Slaughter for Feathers . .		
Egg Collecting of Boys . .		
Food		
Climate		
Cats, Weasels, etc. . . .		
Sparrows, Jays, etc. . . .		

Questions

1. Do birds prefer wild or cultivated fruits?
2. What factor causes the greatest decrease in the number of birds?

3. What is the food of the robin?
4. What birds are seed eaters?
5. Of what importance are the gulls?
6. What are the bird laws of your state?

Special Reports

1. Reasons for migration.
2. Some useful birds.
3. The starling.
4. The English sparrow.
5. The bobwhite.

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"You call them thieves and pillagers ; but know
They are the wingèd wardens of your farms,
Who from your cornfields drive the insidious foe,
And from your harvests keep a hundred harms."

— LONGFELLOW.

THE HUMAN BODY AS A MACHINE

PROBLEM XLI

A study of man as a vertebrate compared with a frog.

a. Comparisons

Observations. — 1. Note that the body of man is divided into two distinct regions, head and trunk. Can you find these in the frog? Is the head movable? How does it differ from that of man?

2. What is the body covering of the frog? How does it differ from that of man? *Note.* — The sliminess of the skin of the frog is due to some cells that pour out mucus.

Conclusions. — 1. Can you think of any use for this secretion?

2. Why should a frog's head be more flattened than that of man?

Observation. — Note the position of the eyes of a frog. How does it differ from the position of the eyes of man?

Conclusion. — Does a frog need a neck as does man? Explain.

Observations. — 1. Note the divisions of a fore limb or arm, into upper arm (forearm) and hand. How many fingers on each hand?

2. How do the fore limbs of a man differ from those of a frog?

Conclusion. — How do the functions of the hand of a man differ from those of a frog?

Observations. — 1. Find the thigh, shank, and foot in the hind leg of a frog.

2. How many toes on each foot? How do the hind feet differ from the front ones?

3. How do the ankle and the foot of man differ from those of the frog?

4. What advantage in the hind legs of a frog being so near the hind end of the body?

Conclusion. — What adaptions for locomotion found in the frog not found in man?

b. A Typical Muscle and its Functions

Material. — Hind legs of a frog preserved in 4 % formalin.

1. Frog

Method. — Strip off the skin of the hind leg.

Observations. — 1. Note the whitish muscle that forms the *calf.* Is it in a solid mass or in bundles?

2. Where is it widest? The wide part is called the *belly.*

3. Look carefully for the endings. Where are they fastened? The glistening white part which attaches a muscle to a bone is called a *tendon.*

4. Pull the large muscle in the calf. What movements result?

5. How are the muscles related to one another?

Conclusions. — 1. What results when a muscle contracts?

2. Should both muscles of a pair contract at once? If so, what would happen?

3. Why is it necessary that muscles be arranged in pairs?

4. What is the advantage of a tendon?

2. The Human Body

Method. — Grasp the upper right arm with the left hand. Raise and lower the forearm a number of times. Find the muscles that form the pair for moving the forearm.

Observations. — 1. Which one is the larger? Why?

2. What changes take place in the muscles of the arm as they are used?

Conclusions. — 1. What happens to a muscle when it shortens?

2. What happens to bones when muscles shorten?

3. Muscles as Part of a Machine

Note. — The instructor should here briefly explain the principle of the lever, as well as the three classes or kinds. Designate them by the factor placed in the middle.

Fig. 53. — Diagram showing action of biceps muscle. *a*, contracted; *b*, extended; *h*, humerus; *s*, scapula.

Method a. — Raise a book in the right hand.

Observation. — Locate the power, weight, and fulcrum. What represents each? Use Figure 53 in locating *P*, *W*, and *F*.

Conclusion. — What class of lever is represented here? (Make a sketch to show your conclusion.)

Method b. — Stand on tiptoe.

Observations. — 1. What is the effect on the muscle in the calf of the leg?

2. Locate weight, fulcrum, and power.

Conclusion. — What class of levers represented here? Make a sketch to show your conclusion.

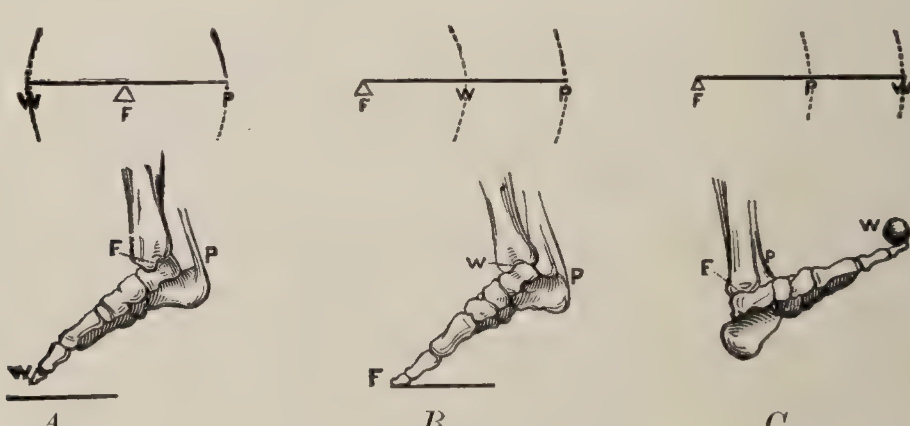

Fig. 54. — Forms of levers. *A*, first class; *B*, second class; *C*, third class; *W*, weight; *F*, fulcrum or pivot; *P*, pull or power.

Method c. — Bend the head backward.

Observations. — 1. Where is the muscle located that pulls the head backward?

2. Locate the power, weight, and fulcrum.

Conclusions. — 1. What class of levers is represented here? Make a sketch to show your conclusion.

2. Show that all three classes of levers are in the foot.

4. Microscopic Structure (Optional)

Materials. — Boiled lean beef, microscope slides, portable or stationary compound microscope, and hand lens.

Method a. — Try pulling the lean beef in strips. Also examine with hand lens.

Observations. — 1. What is the structure of the muscle?

2. Find thin whitish bands scattered throughout the muscle. Describe their appearance.

Conclusions. — 1. How are the fibers of muscles held in place?

2. Compare these fibers with bundles of rubber bands.

Method b. — Examine a bit of muscle with low power of a compound microscope.

Observation. — What do you see concerning the structure of muscle, not seen well with the hand lens? Can you make out the fibers?

Conclusion. — What is lean meat? What is its structure?

c. General Adaptations of the Skeleton

Materials. — Shank bones of calves or sheep from the market — some sawed crosswise, others lengthwise, skeleton of frog or other vertebrate, skeleton of man, charts, HCl, Bunsen burner or alcohol lamp, crucible, scales.

1. Composition

Method. — Weigh two small pieces of bone. Drop one into HCl and allow it to remain until the action ceases. Burn a second piece in a crucible. Weigh what remains in both cases.

Observations. — 1. What is the original weight of each piece?

2. What happens when the bone is put in acid? Its percentage of loss in weight?

3. Is the bone now flexible?

4. What happens when the bone is burned in a crucible? Percentage of loss?

5. Is it flexible after burning?

Conclusions. — 1. What substance is taken out by the acid? By the heat?

2. What is the purpose of each of these two substances?

Observations. — 1. Note the membrane (*periosteum*) covering the larger pieces of bone. Is it attached to the bone loosely or closely?

2. Is it a strong or weak membrane?

Conclusions. — 1. For what does the periosteum seem to be fitted?

2. The periosteum is a living and growing surface on the live bone? Would it probably mend a crack or fracture in the bone? If so, explain.

2. Joints

Observations. — 1. Study a joint of any skeleton, as a frog's. Move the joint. In how many directions will it move?

2. Can it be easily twisted or rotated?

3. Can you tell whether it is hingelike, ball and socket, gliding, or rotary?

4. Note how the joints are held together by a tough tissue (*ligament*). Is it tough? Elastic? Strong?

Conclusions. — 1. How many different kinds of joints can you find in a skeleton?

2. How are the bones of the skeleton held together?

Observation. — Can you find where muscles have been attached to the bone? Are the means of attachment (*tendons*) soft or tough? Elastic or unyielding?

Conclusion. — Why are muscles attached to bones?

3. General Skeleton

Observations. — 1. Note that the skeleton is in two general parts, — the *axial*, of the vertebral column or backbone, and

skull; and the *appendicular*, of the appendages or parts attached to the main axis. Which part is composed of the greater number of bones?

2. Note that the spinal column is composed of many single bones (*vertebræ*). Are they immovable, or flexibly arranged?

3. How many ribs do you find? Are they all alike?

4. Where are the ribs fastened?

Conclusions. — 1. What seems to be the uses of the skeleton?

2. What good purpose in having so many bones in the skeleton?

3. Why is the axial skeleton made up of so many bones?

4. Why is the spinal column curved rather than straight?

d. Nervous System

Materials. — Demonstration specimens of nervous system of a frog.

Observations. — 1. Find the brain of the frog. Note that in front of the brain are two *olfactory* lobes leading to the nostrils. Just back of these find enlargements called *cerebral hemispheres;* just back of these are the *optic* (sight) *lobes* or *midbrain*, followed by a small *cerebellum*, which in turn is followed by a long portion, the *medulla oblongata*, which joins imperceptibly with the long dorsal nerve or *spinal cord.* How far backwards does the spinal cord extend?

2. Note the many pairs of nerves given off from the brain and spinal cord. *Note.* — These nerves branch and rebranch into very minute fibers some of which end in the muscles, and are therefore called *motor* (motion) nerves. Still others pass from the surface of the body inwards. They receive impressions as of touch, light, heat, sound, etc., and are called *sensory* nerves.

3. Compare with the diagram of the nervous system of man.

Conclusion. — If a sensory ending is affected by any external stimulus as noted above, where must the message be carried before the muscles may be influenced?

Questions

1. What is the purpose of a nervous system?
2. What senses do you consider the most important in a frog? In man? Why?
3. Why are the bones in the hind leg of a frog so differently arranged and shaped than the legs of man?
4. Why cannot a frog jump backwards?
5. Distinguish between voluntary and involuntary muscles.
6. Why is a slow walk of little value as exercise?
7. What is the effect of tobacco on muscles?
8. Why should one who works to excel in athletics abstain from the use of alcohol?
9. How is bodily heat produced?
10. Explain how and why the muscles should be exercised.
11. Why do many people have round shoulders?
12. Why are some forms of exercise better than others?
13. What is flesh?
14. Why is exercise in the open air best?
15. Why is strict training necessary for success in athletics?
16. What is tetanus?
17. What is the difference between a break and a sprain?
18. Explain how to care for broken bones.
19. Why avoid heavy strains on the bones of the young?
20. How treat a sprain? A break?
21. What is the dislocation of a bone? How treat it?
22. Show on the arm of another pupil just how you would treat a fracture, pending the arrival of a surgeon.
23. Why are low desks injurious to the young?
24. Why should deformities be corrected in youth?
25. How can you tie a knot in a bone?
26. Why is the shoulder more often dislocated than the hip?
27. May high pillows be injurious? How?
28. Should young children be urged to walk early? Explain.
29. What is the use of cartilage? What is marrow?

Special Reports

1. Man as a vertebrate. Comparison with other vertebrates.
2. Massage and its benefits.
3. Methods for developing muscles in the gymnasium.
4. Methods for exercising.
5. Proper care of the muscles.
6. Methods of training for athletic contests.
7. Spasms and how to manage.
8. The care of sprains.

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FOODS AND DIETARIES

PROBLEM XLII

A study of food values and diets.

Method. — Refer to the tables and Figures in the following pages.

a. Food Values and Cost[1] (Method I, Portions)

COMPARATIVE VALUES AND PRICES OF FOOD MATERIALS[2]

(See Summary I for additional data.)

Kind of Food	Price per Pound	10 Cents will Purchase —		Kind of Food	Price per Pound	10 Cents will Purchase —	
		Proteid	Fats and Carbo. (Energy)			Proteid	Fats and Carbo. (Energy)
Beef	*Cents*	*Pound*	*Calories*[3]	*Beef — Cont.*	*Cents*	*Pound*	*Calories*
Tenderloin steak	25	.064	415	Rump	12	.114	920
Sirloin steak. .	20	.081	520	Shoulder . . .	10	.115	920
Short steak . .	20	.081	520	Second cut round . . .	8	.205	745
Loin roast . .	18	.090	580	Neck	7	.207	1,100
Rib roast . . .	16	.088	730	Brisket. . . .	6	.200	1,946
First cut round.	16	.130	560	Plate	6	.230	2,150
Round steak. .	14	.135	635	Flank	6	.284	1,860
Chuck	12	.129	765	Shank	5	.256	1,090

[1] Average market in 1902. 10 cents will purchase fully 20 % less to-day.

[2] Milner, Reprint from Yearbook, Department of Agriculture, 1902.

[3] A calorie is here defined as the amount of heat required to raise one kilogram of water (1000 cubic centimeters) one degree centigrade.

Kind of Food	Price per Pound	10 Cents will Purchase —	
		Proteid	Fats and Carbo. (Energy)
Veal	*Cents*	*Pound*	*Calories*
Cutlets	23	.089	310
Loin and rib . .	18	.093	385
Leg	16	.098	390
Shoulder or breast . . .	12	.180	530
Chuck and neck	12	.133	425
Knuckle or shank . . .	6	.346	985
Flank	6	.424	1,370
Mutton and Lamb			
Loin	18	.076	810
Leg	14	.107	640
Chuck and shoulder . .	12	.099	1,120
Neck		.243	1,970
Flank	10	.276	3,630
Pork			
Smoked ham .	20	.071	840
Bacon	14	.065	1,985
Smoked shoulder	13	.108	1,130
Fresh ham . .	12	.112	1,120
Fresh shoulder .	10	.120	1,480
Ribs and loin .	10	.134	1,270
Fat salt pork . .	10	.019	3,670

Kind of Food	Price per Pound	10 Cents will Purchase —	
		Proteid	Fats and Carbo. (Energy)
Poultry	*Cents*	*Pound*	*Calories*
Turkey . . .	18	.092	600
Chicken . . .	15	.092	520
Fish			
Salmon, fresh .	35	.040	175
Halibut, smoked	20	.097	475
Cod, salt, boneless	20	.139	275
Halibut, fresh .	18	.080	265
Salmon, canned	15	.146	615
Shad	12	.078	315
Bluefish . . .	12	.083	175
Mackerel, fresh	12	.096	305
Cod, fresh . .	12	.141	280
Mackerel, salt .	8	.204	1,290
Cod, salt . . .	9	.211	350
Lobster, canned	35	.052	175
Oysters, "solids"	18[1]	.030	130
Lobster, fresh	16	.037	90
Clams in shell .	([2])	.025	79
Miscellaneous			
Sausage . . .	10	.130	2,125
Lard	9	——	4,685
Dairy Products, etc.			
Butter	28	.004	1,300
Eggs (per dozen)	16	.083	400

[1] 35 cents a quart. [2] 40 cents a peck.

Kind of Food	Price per Pound	10 Cents will Purchase —		Kind of Food	Price per Pound	10 Cents will Purchase—	
		Proteid	Fats and Carbo. (Energy)			Proteid	Fats and Carbo. (Energy)
Dairy Products, etc. — Cont.	*Cents*	*Pound*	*Calories*	*Vegetables — Cont.*	*Cents*	*Pound*	*Calories*
Cheese	16	.163	1,230	Turnips	1	.090	1,250
Whole milk	3[1]	.110	1,080				
Skimmed milk	1.5[2]	.203	1,130	*Cereal Products*			
Cream	15[3]	.034	1,220				
Condensed milk	12	.073	1,260	Crackers	8	.134	2,380
				Rice	8	.100	2,040
Vegetables							
Canned corn	15	.028	455	Wheat breakfast foods[4]	7.5	.161	2,260
Canned peas	12	.030	215	Oatmeal[4]	7.5	.222	2,460
Baked beans, canned	12	.058	500	Buckwheat	6	.069	2,770
				Barley	5	.170	3,300
				Hominy	5	.166	3,300
Canned tomatoes	6	.020	175	Bread, white	5	.184	2,430
Celery	5	.045	350				
Dried beans	4	.562	4,010	Wheat breakfast food[5]	4	.302	4,250
Split peas	4	.615	4,400	Oatmeal[5]	4	.418	4,625
Green beans	3	.136	1,230	Rye flour	3	.227	5,430
Green peas	3	.105	850	Wheat flour	3	.380	5,490
String beans	3	.067	600	Graham flour	3	.443	5,580
Onions	3	.047	685				
Squash	3	.023	350	Entire wheat flour	3	.460	5,580
Pumpkins	3	.017	200	Corn meal	2.5	.368	6,620
Cauliflower	2.5	.043	560				
Cabbage	2.5	.056	500				
Sweet potatoes	2	.060	1,900	*Sugars, Starches, etc.*			
Green corn	2	.060	900				
Parsnips	1.5	.069	1,600	Cornstarch	8	——	2,080
Beets	1.5	.069	1,130	Tapioca	6	——	2,780
Potatoes	1.5	.120	2,070	Sugar	6	——	3,130

[1] 6 cents a quart. [2] 3 cents a quart. [3] 25 cents a quart.
[4] As put up in packages. [5] In bulk.

Kind of Food	Price per Pound	10 Cents will Purchase —		Kind of Food	Price per Pound	10 Cents will Purchase —	
		Proteid	Fats and Carbo. (Energy)			Proteid	Fats and Carbo. (Energy)
Sugars, Starches, etc. — Cont.	*Cents*	*Pound*	*Calories*	*Fruits — Cont.*	*Cents*	*Pound*	*Calories*
				Canned peaches	8	.009	280
				Bananas . . .	7	.011	430
Molasses . . .	6	——	2,580	Oranges . . .	7	.011	345
Olive oil . . .	75	——	565	Berries	6	.007	290
				Cherries . . .	6	.015	575
Fruits				Muskmelon . .	5	.006	180
Figs	16	.027	930	Cranberries . .	4	.010	535
Dates	10	.019	1,095	Fresh peaches .	4	.025	635
Prunes	10	.018	1,190	Pears	3	.020	980
Raisins	10	.023	1,445	Grapes	3	.033	1,120
Pineapple . .	10	.004	200	Watermelon . .	3	.006	200
Dried apples . .	10	.016	1,350	Apples	1.5	.027	930
Dried apricots .	10	.047	1,290				

NOTE. — Grams of proteid or carbohydrates may be reduced to calories by multiplying by 4.1, of fats by 9.3; ounces of proteid and carbohydrate by multiplying by 116, of fats by 264.

Observations. — 1. Do foods furnish nutrients in the same proportions? At the same cost? Explain.

2. Are the best foods the costliest? Explain. See Figure 55.

3. Are the cheapest foods those that are the least nutritious?

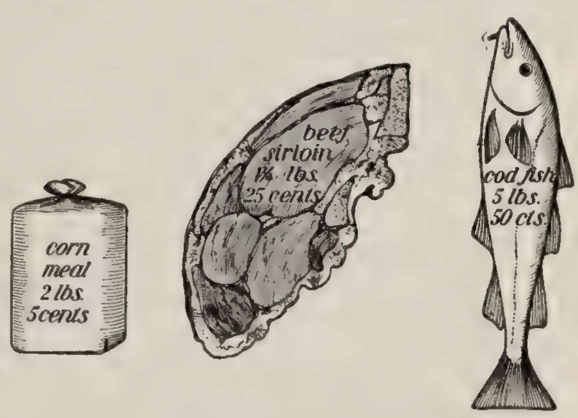

FIG. 55. — Diagram showing the difference in cost of three foods, each of which furnishes about the same amount of nourishment.

Conclusions. — 1. Illustrate what you mean by a cheap food. An expensive one.

2. Show how a food may be an expensive source of proteid, and yet a cheap source of energy.

b. Nutritive Values as compared with Cost

1. As Sources of Proteid (Tissue Builders)

Note. — Foods may be considered as cheap that furnish more than .15 pound of proteid for 10 cents at ordinary prices.

Observation. — Refer to the table and list those foods that appear cheap as sources of proteid.

Note. — Foods may be considered as medium-priced that furnish from .075 to .15 pound of proteid for 10 cents at ordinary prices.

Observation. — Write out a list of the medium-priced sources of proteid as given in the table.

Note. — Foods are considered as expensive if they furnish less than .075 pound of proteid for 10 cents at ordinary prices.

Observation. — Refer to the table and list the foods given that are considered expensive sources of proteid.

2. As Sources of Energy, or Fuel

Note. — Foods may be considered as cheap if they furnish more than 1900 units of energy for 10 cents at ordinary prices.

Observation. — List as many cheap energy producers as you can.

Note. — Foods may be considered as medium-priced if they furnish from 800 to 1900 units of energy for 10 cents at ordinary prices.

Observation. — What foods fulfill the requirements for being medium-priced?

Note. — Those foods furnishing less than 800 units of energy for 10 cents may be considered as expensive energy producers.

Conclusions. — 1. What foods are cheap both as proteid producers and as energy producers?

2. What foods are expensive both as energy producers and as proteid producers?

Note. — Some foods that are otherwise expensive may sometimes be justifiable for the sake of variety, and to please the palate, or as appetizers. Can you name any such?

3. What are the condiments? What is their function?

4. What are stimulants? Flavors? What are their functions?

c. The Family Dietary

1. Daily Calorie Needs (Approximately)

Observations: —

1.	For child under 2 years	900 calories.
2.	For child from 2 to 5 years	1200 calories.
3.	For child from 6 to 9 years	1500 calories.
4.	For child from 10 to 12 years	1800 calories.
5.	For girl from 12 to 14 years (woman, light work, also)	2100 calories.
6.	For boy from 12 to 14, girl from 14 to 16 (man, sedentary)	2400 calories.
7.	For boy from 15 to 16 years (man, light muscular work)	2700 calories.
8.	For man (moderately active muscular work)	3000[1] calories.
9.	For farmer (busy season)	3200 to 4000 calories.
10.	For ditchers, excavators, etc.	4000 to 5000 calories.
11.	Lumbermen, etc.	5000 and more calories.

Note. — An average result for light work may also be obtained by multiplying the body weight in pounds by 16.1 calories.

Conclusions. — 1. Refer to the above table and determine approximately your own daily calorie needs.

2. Determine the daily calorie needs for your own family.

2. Daily Dietary

Observation. — Dr. R. H. Chittenden[2] of Yale University concludes that we need proteids, fats, and carbohydrates in about

[1] Chittenden also gives 60 grams of proteid to 2700 calories of energy.

[2] Atwater gives ratios of 1.4 proteid to 3.4 fat to 5.2 carbohydrate. Voit gives 2.5 proteid to 2 fat to 5.5 carbohydrate and is considered authoritative by many.

the ideal ratio of 1 to 3 to 6. How many calories of each in every 100?

Dr. Irving Fisher of Yale University has worked out tables of what is known as the 100 calorie portion, mentioned in the following tables.

Refer to Dr. Fisher's tables and fill in the values for your own daily dietary after the following model.

(a) Sample Day's Dietary

Total Calories		Calories from Proteid	Calories from Fat	Calories from Carbohydrates	Market Price	Computed Price for Proteid	Calories for Ten Cents
Breakfast							
1 shredded wheat biscuit yields	100	13	4.5	82.5			
1 slice of bread yields	100	13	6	81			
1 serving of apple sauce yields	100	2	5	93			
1 small square of butter yields	100	.5	99.5	0			
¼ cup of cream yields	100	5	86	9			
Calories from breakfast	500	33.5	201	265.5			
Dinner							
1 large serving boiled beef, lean, yields	100	90	10	0			
1 good-sized baked potato yields	100	11	1	88			
1 serving of spinach yields	50	7.5	33	9.5			
2 pats of butter yield	200	1	199	0			
2 slices of bread yield	200	26	12	162			
2 small servings cream rice pudding yield	200	16	26	158			
Calories from dinner	850	151.5	281	417.5			

Total Calories		Calories from Proteid	Calories from Fat	Calories from Carbohydrates	Market Price	Computed Price for Proteid	Calories for Ten Cents
Supper							
3 slices of bread yield	300	39	18	243			
2 small glasses of milk yield	200	38	104	58			
¼ glass of cream yields	100	5	86	9			
6 prunes yield . . .	200	6	0	194			
Calories from supper	800	88	208	405			
Day's total, calories	2150						

The day's total dietary has furnished 2150 calories. Assuming the body weight to be 140 pounds, and the day's work to be light, the calculated food need, 140 times 16.1 calories, or 2254 calories, is found to correspond closely to the actual amount required, as given on page 231.

Name ------------------------- Age------ Weight------lbs.

Daily calorie needs --

Amount computed--

Discrepancy--

Conclusions. — 1. How does the day's total of calories used compare with that given in the table of daily needs for a person of your age?

2. If there is any discrepancy, how can you account for it?

3. How much proteid furnished for 10 cents? How many units energy?

4. Is your listed diet cheap, medium-priced, or expensive? Reasons?

5. Can you suggest where it might be improved?

6. Try forming a diet giving least quantities of nutrients so that they total your daily calorie needs.

Observation. *Home Work.* — Fill out a similar table for your family dietary for one or more days. Lump the portions used at a meal, and figure out the data for the rest of the tabulation. (The average for one week would be best.)

Conclusions. — 1. Is your family dietary cheap, medium-priced, or expensive? Reasons? (Answer as proteid producer and energy producer.)

2. Can you suggest how it might be improved? Explain.

3.[1] Would your family be content to use more milk and eggs, and meat not more than once a day? Which would be the cheaper?

(*b*) *Table of* 100 *Food Units*[2]

Name of Food	Portion containing 100 Food Units (Approx.)	Wt. of 100 Calories (oz.)	Calories furnished by		
			Proteid	Fat	Carbohydrates
Cooked Meats					
Beef, round, boiled (fat) . . .	Small serving . .	1.3	40	60	0
Beef, round, boiled (lean) . . .	Large serving . .	2.2	90	10	0
Beef, round, boiled (med.) . . .	Small serving . .	1.6	60	40	0
Beef, 5th rib, roasted	Half serving . .	.65	12	88	0
Beef, 5th rib, roasted	Small serving . .	1.2	25	75	0
Beef, 5th rib, roasted	Very sm. serving	.88	18	82	0
Beef, ribs, boiled	Small serving . .	1.1	27	73	0
Beef, ribs, boiled	Very sm. serving	.87	21	79	0
Calf's-foot jelly	. . . .	4	19	0	81
Chicken, canned	One thin slice . .	.96	23	77	0
Lamb chops, boiled, av. . . .	One small chop .	.96	24	76	0
Lamb, leg, roasted	Ord. serving . .	1.8	40	60	0

[1] Much excess of proteid (as from lean meats, etc.) is to be avoided, as it is by far the most expensive nutrient, and besides being a costly waste may result in bodily disorder.

[2] These tables are here given by courtesy of *The Journal of the American Medical Association*, Vol. XLVIII, No. 16; they were compiled by Dr. Irving Fisher, Yale University.

Name of Food	Portion containing 100 Food Units (Approx.)	Wt. of 100 Calories (oz.)	Calories furnished by		
			Proteid	Fat	Carbohydrates
Cooked Meats — Cont.					
Mutton, leg, boiled	Large serving	1.2	35	65	0
Pork, ham, boiled (fat)	Small serving	.73	14	86	0
Pork, ham, boiled	Ord. serving	1.1	28	72	0
Pork, ham, roasted (fat)	Small serving	.96	19	81	0
Pork, ham, roasted (lean)	Small serving	1.2	33	67	0
Turkey as purchased canned	Small serving	.99	23	77	0
Veal, leg, boiled	Large serving	2.4	73	27	0
Uncooked Meats, Edible Portion					
Beef, loin, av. (lean)	Ord. serving	1.8	40	60	0
Beef, loin, av. (fat)	Small serving	1.1	22	78	0
Beef, loin, porterhouse steak, av.	Small steak	1.3	32	68	0
Beef, loin, sirloin steak, av.	Small steak	1.4	31	69	0
Beef, ribs, lean, av.	Ord. serving	1.8	42	58	0
Beef, round, lean, av.	Ord. serving	2.2	54	46	0
Beef, tongue, av.	Ord. serving	2.2	47	53	0
Beef, juice	. . . .	14	78	22	0
Chickens (broilers) av.	Large serving	3.2	79	21	0
Clams, round in shell, av.	12 to 16	7.4	56	8	36
Cod (whole)	Two servings	4.9	95	5	0
Goose (young) av.	Half serving	.88	16	84	0
Halibut steaks, av.	Ord. serving	2.8	61	39	0
Liver (veal), av.	Two sm. servings	2.8	61	39	0
Lobster (whole), av.	Two servings	4.1	78	20	2
Mackerel (Span.), whole, av.	Ord. serving	2	50	50	0
Mutton, leg, hind, lean, av.	Ord. serving	1.8	41	59	0
Oyster in shell, av.	One dozen	6.8	49	22	29
Pork, loin, chops, av.	Very sm. serving	.97	18	82	0
Pork, ham, lean, av.	Small serving	1.3	29	71	0
Pork, bacon, med. fat, av.	Small serving	.53	6	94	0
Salmon (Cal.), av.	Small serving	1.5	30	70	0
Shad, whole, av.	Ord. serving	2.1	46	54	0
Trout, brook, whole, av.	Two sm. servings	3.6	80	20	0
Turkey, av.	Two sm. servings	1.2	29	71	0
Vegetables					
Artichokes, av., canned	. . . .	15	14	0	86
Asparagus, av., canned	. . . .	19	33	5	62
Asparagus, av., cooked	. . . .	7.19	18	63	19

Name of Food	Portion containing 100 Food Units (Approx.)	Wt. of 100 Calories (oz.)	Calories furnished by		
			Proteid	Fat	Carbohydrates
Vegetables — Cont.					
Beans, baked, canned	Small side dish .	2.66	21	18	61
Beans, lima, canned	Large side dish .	4.44	21	4	75
Beans, string, cooked	Five servings . .	16.66	15	48	37
Beets, edible portion, cooked .	Three servings .	8.7	2	23	75
Cabbage, edible portion . . .	. . . .	11	20	8	72
Carrots, edible portion, fresh .	. . . .	7.6	10	8	82
Carrots, cooked	Two servings . .	5.81	10	34	56
Cauliflower, as purchased . .	. . . .	11	23	15	62
Celery, edible portion	. . . .	19	24	5	71
Corn, sweet, cooked	One side dish . .	3.5	13	10	77
Cucumbers, edible portion . .	. . . .	20	18	10	72
Egg plant, edible portion . . .	. . . .	12	17	10	73
Lentils, cooked	. . . .	3.15	27	1	72
Lettuce, edible portion	. . . . . .	18	25	14	61
Mushrooms, as purchased . .	. . . .	7.6	31	8	61
Onions, fresh, edible portion . .	. . . .	7.1	13	5	82
Onions, cooked	Two l'ge servings	8.4	12	40	48
Parsnips, edible portion . . .	One one half serv.	5.3	10	7	83
Parsnips, cooked	. . . .	5.84	10	34	56
Peas, green, canned	Two servings . .	6.3	25	3	72
Peas, green, cooked	One serving . .	3	23	27	50
Potatoes, baked	One good-sized .	3.05	11	1	88
Potatoes, boiled	One large-sized .	3.62	11	1	88
Potatoes, mashed (creamed) . .	One serving . .	3.14	10	25	65
Potatoes, steamed	One serving . .	3.57	11	1	88
Potatoes, chips	One half serving .	.6	4	63	33
Potatoes, sweet, cooked . . .	Half av. potato .	1.7	6	9	85
Pumpkins, edible portion . . .	. . . .	13	15	4	81
Radishes, as purchased . . .	. . . .	17	18	3	79
Rhubarb, edible portion . . .	. . . .	15	10	27	63
Spinach, cooked	Two ord. servings	6.1	15	66	19
Squash, edible portion	. . . .	7.4	12	10	78
Succotash, canned	Ord. serving . .	3.5	15	9	76
Tomatoes, fresh, as purchased .	Four av. servings	15	15	16	69
Tomatoes, canned	. . . .	15.2	21	7	72
Turnips, edible portion . . .	Two l'ge servings	8.7	13	4	83
Vegetable oysters	. . . .	9.62	10	51	39

Name of Food	Portion containing 100 Food Units (Approx.)	Wt. of 100 Calories (oz.)	Calories furnished by		
			Proteid	Fat	Carbohydrates
Fruits (Dried)					
Apples, as purchased	. . . .	1.2	3	7	90
Apricots, as purchased	. . . .	1.24	7	3	90
Dates, edible portion	Three large	.99	2	7	91
Dates, as purchased	. . . .	1.1	2	7	91
Figs, edible portion	One large	1.1	5	0	95
Prunes, edible portion	Three large	1.14	3	0	97
Prunes, as purchased	. . . .	1.35	3	0	97
Raisins, edible portion	. . . .	1	3	9	88
Raisins, as purchased	. . . .	1.1	3	9	88
Fruits (Fresh or Cooked)					
Apples, as purchased	Two apples	7.3	3	7	90
Apples, baked	. . . .	3.3	2	5	93
Apples, sauce	Ord. serving	3.9	2	5	93
Apricots, edible portion	. . . .	5.92	8	0	92
Apricots, cooked	Large serving	4.61	6	0	94
Bananas, edible portion	One large	3.5	5	5	90
Blackberries	. . . .	5.9	9	16	75
Blueberries	. . . .	4.6	3	8	89
Blueberries, canned	. . . .	5.8	4	9	87
Cantaloupe	Half ord. serving	8.6	6	0	94
Cherries, edible portion	. . . .	4.4	5	10	85
Cranberries, as purchased	. . . .	7.5	3	12	85
Grapes, as purchased, av.	. . . .	4.8	5	15	80
Grapefruit	. . . .	7.57	7	4	89
Grape juice, small glass	. . . .	4.2	0	0	100
Gooseberries	. . . .	9.2	5	0	95
Lemons	. . . .	7.57	9	14	77
Lemon juice	. . . .	8.77	0	0	100
Nectarines	. . . .	5.18	4	0	96
Olives, ripe	About seven	1.31	2	91	7
Oranges, as purchased, av.	One very large	9.4	6	3	91
Oranges, juice	Large glass	6.62	0	0	100
Peaches, as purchased, av.	Three ordinary	10	7	2	91
Peaches, sauce	Ord. serving	4.78	4	2	94
Peaches, juice	Ord. glass	4.80	0	0	100
Pears	One large	5.40	4	7	89
Pears, sauce	. . . .	3.98	3	4	93

Name of Food	Portion containing 100 Food Units (Approx.)	Wt. of 100 Calories (oz.)	Calories furnished by		
			Proteid	Fat	Carbohydrates
Fruits (Fresh or Cooked) — Cont.					
Pineapples, edible portion, av.	. . . .	8	4	6	90
Raspberries, black	. . . .	5.18	10	14	76
Raspberries, red	. . . .	6.29	8	0	92
Strawberries, av.	Two servings	9.1	10	15	75
Watermelon, av.	. . . .	27	6	6	88
Dairy Products					
Butter, ordinary pat	1 pat	.44	.5	99.5	0
Buttermilk	1½ glasses	9.7	34	12	54
Cheese, Am. pale	1½ cubic in.	.77	25	73	2
Cheese, cottage	4 cubic in.	3.12	76	8	16
Cheese, full cream	1½ cubic in.	.82	25	73	2
Cheese, Neufchatel	1½ cubic in.	1.05	22	76	2
Cheese, Swiss	1½ cubic in.	.8	25	74	1
Cheese, pineapple	1½ cubic in.	.72	25	73	2
Cream	¼ ord. glass	1.7	5	86	9
Kumyss	. . . .	6.7	21	37	42
Milk, condensed, sweetened	. . . .	1.06	10	23	67
Milk, condensed, unsweetened	. . . .	2.05	24	50	26
Milk, skimmed	1½ glass	9.4	37	7	56
Milk, whole	Small glass	4.9	19	52	29
Whey	Two glasses	13	15	10	75
Cakes, Pastry, Puddings, and Desserts					
Cake, chocolate layer	½ ord. sq. piece	.98	7	22	71
Cake, gingerbread	½ ord. sq. piece	.96	6	23	71
Cake, sponge	Small piece	.89	7	25	68
Custard, caramel	. . . .	2.51	19	10	71
Custard, milk	Ord. cup	4.29	26	56	18
Custard, tapioca	Two thirds ord.	2.45	9	12	79
Doughnuts	Half a doughnut	.8	6	45	49
Lady fingers	. . . .	.95	10	12	78
Macaroons	. . . .	.82	6	33	61
Pie, apple	One third piece	1.3	5	32	63
Pie, cream	One fourth piece	1.1	5	32	63
Pie, custard	One third piece	1.9	9	32	59
Pie, lemon	One third piece	1.35	6	36	58

Name of Food	Portion containing 100 Food Units (Approx.)	Wt. of 100 Calories (oz.)	Calories furnished by		
			Proteid	Fat	Carbohydrates
Cakes, Pastry, Puddings, and Desserts — Cont.					
Pie, mince	One fourth piece	1.2	8	38	54
Pie, squash	One third piece	1.9	10	42	48
Pudding, apple sago	. . . .	3.02	6	3	91
Pudding, brown betty	Half ord. serving	2	7	12	81
Pudding, cream rice	Very small serving	2.65	8	13	79
Pudding, Indian meal	Half ord. serving	2	12	25	63
Pudding, apple tapioca	Small serving	2.8	1	1	98
Tapioca, cooked	Ord. serving	3.85	1	1	98
Sweets and Pickles					
Catsup, tomato, av.	. . . .	6	10	3	87
Honey	Four teaspoons	1.05	1	0	99
Marmalade, orange	. . . .	1	.5	2.5	97
Molasses, cane	. . . .	1.2	.5	0	99.5
Olives, green, edible portion	Seven olives	1.1	1	84	15
Olives, ripe, edible portion	Seven olives	1.3	2	91	7
Pickles, mixed	. . . .	14.6	18	15	67
Sugar, granulated	Three teaspoons or 1½ lumps	.86	0	0	100
Sugar, maple	Four teaspoons	1.03	0	0	100
Syrup, maple	Four teaspoons	1.2	0	0	100
Nuts, Edible Portion					
Almonds, av.	Eight to fifteen	.53	13	77	10
Beechnuts	. . . .	.52	13	79	8
Brazil nuts	Three ord. size	.49	10	86	4
Butternuts	. . . .	.50	16	82	2
Coconuts	. . . .	.57	4	77	10
Chestnuts, fresh, av.	. . . .	1.4	10	20	70
Filberts, av.	Ten nuts	.48	9	84	7
Hickory nuts	. . . .	.47	9	85	6
Peanuts	Thirteen, double	.62	20	63	17
Pecans, polished	About eight	.46	6	87	7
Pine nuts (pignolias)	About eighty	.56	22	74	4
Walnuts, California	About six	.48	10	83	7
Cereals					
Bread, brown, av.	Ord. thick slice	1.5	9	7	84

Name of Food	Portion containing 100 Food Units (Approx.)	Wt. of 100 Calories (oz.)	Calories furnished by		
			Proteid	Fat	Carbohydrates
Cereals — Cont.					
Bread, corn (johnnycake), av.	Small square	1.3	12	16	72
Bread, white, homemade	Ord. thick slice	1.3	13	6	81
Corn flakes, toasted	Ord. cereal dish	.97	11	1	88
Corn meal, granular, av.	. . . .	.96	10	5	85
Corn meal, unbolted, av.	. . . .	.92	9	11	80
Crackers, graham	Two crackers	.82	9	20	71
Crackers, oatmeal	Two crackers	.81	11	24	65
Hominy, cooked	Large serving	4.2	11	2	87
Macaroni, av.	. . . .	.96	15	2	83
Macaroni, cooked	Ord. serving	3.85	14	15	71
Oatmeal, boiled	1½ serving	5.6	18	7	75
Popcorn	. . . .	.86	11	11	78
Rice, uncooked	. . . .	.98	9	1	90
Rice, boiled	Ord. cereal dish	3.1	10	1	89
Rice, flakes	Ord. cereal dish	.94	8	1	91
Rolls, Vienna, av.	One large roll	1.2	12	7	81
Shredded wheat	One biscuit	.94	13	4.5	82.5
Spaghetti, av.	. . . .	.97	12	1	87
Wheat flour, entire wheat, av.	. . . .	.96	15	5	80
Wheat flour, graham, av.	. . . .	.96	15	5	80
Wheat flour, patent, family, and straight, grade, spring wheat, av.	. . . .	.97	12	3	85
Zwieback	Size of thick slice of bread	.81	9	21	70
Miscellaneous					
Eggs, hen's, boiled	One large egg	2.1	32	68	0
Eggs, hen's, whites	. . . .	6.4	100	0	0
Eggs, hen's, yolks,	Two yolks	.94	17	83	0
Omelet	. . . .	3.3	34	60	6
Soup, beef, av.	. . . .	13	69	14	17
Soup, bean, av.	Very large plate	5.4	20	10	80
Soup, cream of celery	Two plates	6.3	16	47	37
Consommé	. . . .	29	85	0	15
Clam chowder	Two plates	8.25	17	18	65
Chocolate, bitter	Half a square	.56	8	72	20
Cocoa	. . . .	.69	17	53	30
Ice cream (Phila.)	. . . .	1.6	5	62	33

Note.—Should one desire to add further items to the above table, obtain Bulletin 28, U. S. Department of Agriculture, "The Chemical Composition of American Food Materials," by Atwater and Bryant. (Send 5 cents in coin to Superintendent of Documents, Washington, D.C.) The weight in ounces of a standard portion equals 1600 divided by number of calories per pound given in table. The calories furnished by proteid equal the percentage of proteid given in the Bulletin table multiplied by 1860 and divided by the number of calories per pound. The same calculation and factor applies to carbohydrates. For fat, calculate the same way, but use the factor 4220 in place of 1860. Verify the three results by adding to see if they equal 100 calories.

d. Food Values (Method II, Graphic)

Observations.—1. The threefold constitution of any particular food may be represented graphically by the position of a point *O* in a triangle *CPF* (Fig. 56). Thus the point *O*, representing milk, is located at a height above *CF*, 19 % of the total height of *P*, which shows that 19 % of the food value of milk is proteid; and at a distance to the right of *CP* towards *F*, 52 % of the distance, signifying that 52 % of the food value of milk is fat. Where would you locate the point *O* for a food which was 90 % proteid? 90 % fat?

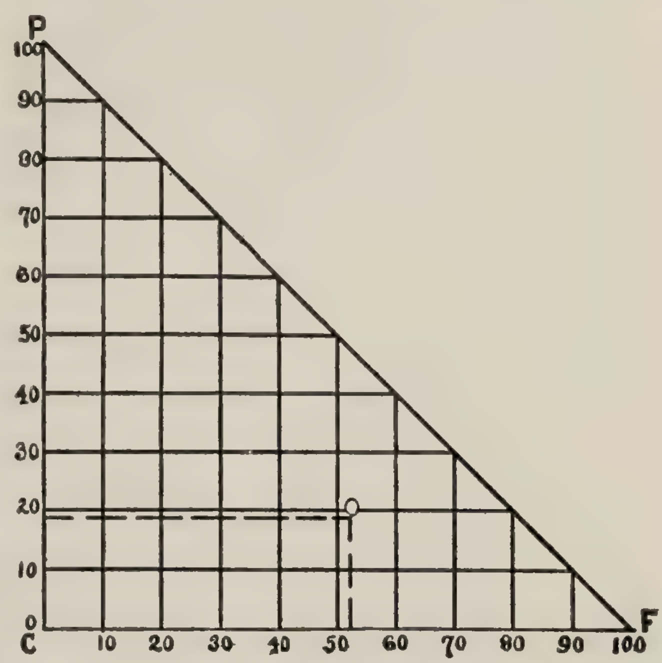

FIG. 56.—Food map. Composition of milk represented by the point *O*. (After Fisher.)

Conclusions.—1. Explain how *P* might be called the proteid corner, *F* the fat corner, and *C* the carbohydrate corner.

2. On what line would a food devoid of proteid be located? If devoid of fat?

Observations. — 1. Two or more foods may be plotted as follows: The combination, if equal in calorie value, is represented by a point midway between them. If the portions are unequal, the point *O* will of course be proportionally nearer the point locating the larger portion. Likewise, when three foods are combined, the point is first located for two, then this with the third, this with the fourth, etc. Thus in Figure 57 we have three points representing respectively 300, 400, and 500 calories of three separate foods. We first join any two points as 300 and 400, and find their combination of 700 calories at the point 700 which divides the line joining the 300 and 400, as 3 to 4 and nearer the 400. We now unite this with the 500 and find a new result at the point 1200. It is now evident any number of portions may be thus combined, the final number obtained equaling the sum of the portions, and its location representing its value as a food. What is the percentage composition of the combination of foods represented by the figure 1200? *Note.* — If the lines *CF* and *CP* are used to compute the percentage of proteid and fat, how can you get the percentage of carbohydrate?

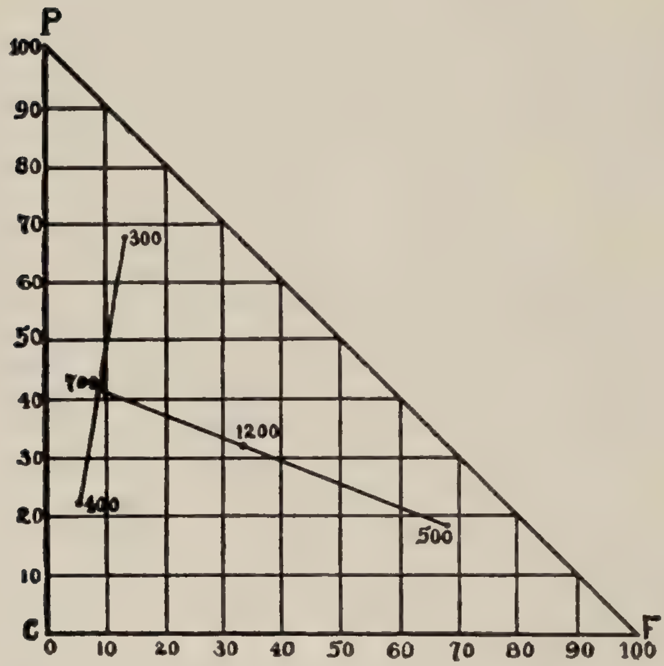

Fig. 57. — Food map. Showing method of combining three or more foods. (After Fisher.)

2. Professor Chittenden believes that, of each 100 calories used, 10 should be proteid, 30 should be fat, and 60 carbohydrate. Locate this combination on a food map. Does it fall within the rectangle *wxyz*, in Figure 58? *Note.* — The rectangle *wxyz* is known as the *normal rectangle*, and shows

where the point O of a well-balanced food or combination of foods would be approximately located. Locate other ratios (see note 2, page 231).

Conclusions. — 1. Are the following menus poor or well balanced? *Note.* — See that the value of each is approximately 900 calories. Why?

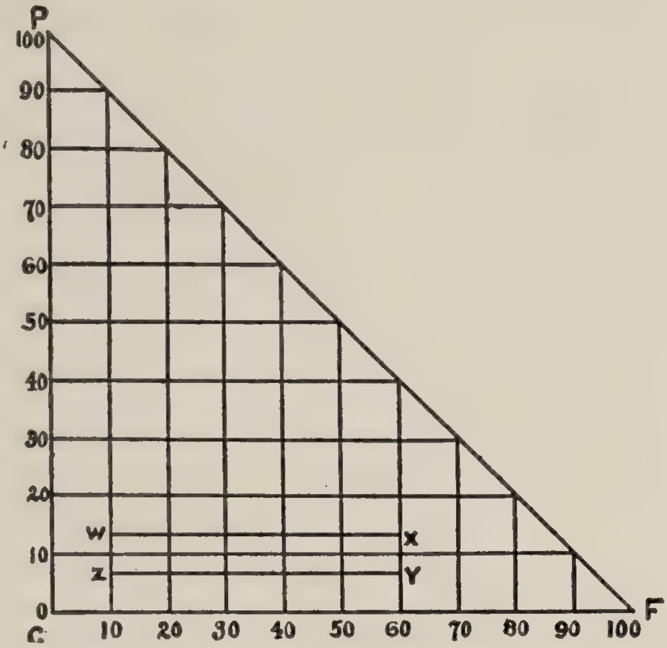

FIG. 58. — Food map. Showing "Normal Rectangle," *wxyz*. Chittenden's standard of well-balanced ration. (After Fisher.)

[1] Menu I. — Eggs.
Bread and butter.

Menu II. — Baked beans.
Brown bread.
Apple sauce.

Menu III. — Oatmeal.
Milk and sugar.
Fruit.

Menu IV. — Cream soup.
Bread and butter.
Potatoes.
Cabbage.
Baked apples and cream.

Menu V. — Pot roast with rice.
Baked apples.

2. Is the following menu well or poorly planned? Show how you obtain your answer.

Menu VI. — Eggs (4 large).
Mashed potatoes (2 servings).
Baked sweet potatoes (1 large).
Custard pie ($\frac{1}{3}$ piece).

[1] Use the number of portions of each article of the menus you think would best suit your appetite, only seeing that the total is 900 calories.

3. Study the following menu and answer the following questions.

Menu VII. — Crackers (4 large).
Lettuce (18 oz.).
Oysters (4 doz.).
Oranges (2 large).

(1) What is its nutritive value in proteid? In calories?
(2) What is its cost? Is it cheap or expensive?
(3) Is it well balanced?

4. Calculate the amount of proteid, carbohydrates, and fat in your own diet for one day. What is its cost? Is it well balanced?

EXTRA MENUS TO MAP

Menu VIII. — Whole wheat bread.
Whole milk.
Prunes.

Menu IX. — Oatmeal with sugar and cream.
Apricots.

Menu X. — Bread.
Cheese.
Onions.

Menu XI. — Eggs.
Mashed potatoes.
Macaroni.
Bread and butter.
Bread pudding.

Questions

1. What is meant by a balanced diet?
2. What is a daily ration for an adult?
3. What are the uses of the nutrients of foods?
4. What are the reasons for cooking foods?
5. What are some of the causes of constipation?
6. What is a food unit?
7. How is the normal rectangle located on a food map? Construct one, using Chittenden's ratios. Atwater's ratios. Voit's ratios.
8. What is the necessity for a mixed diet?
9. Name some common errors in diet.

10. What is the value of soups as foods?

11. What is a fireless cooker? What is its main value?

12. How does milk compare with eggs in food value?

13. How do nuts compare with meat as a source of proteid? Which is the cheaper?

14. Discuss the subject of poultry as food, — its value, cost, etc.

15. Explain how beans and peas may well be called "the lean meat of the vegetable kingdom."

16. How does rice compare with wheat as a food?

17. What are the condiments and flavors? What is their use?

18. Of what importance is diet in sickness?

19. Why do Arctic-living tribes live almost exclusively on blubber, or fat?

20. What are the uses of inorganic foods?

21. What is known about alcohol as a food? Nicotine?

22. How does ten cents' worth of beans compare in food value with ten cents' worth of lobster?

23. How do animal foods compare in cost with vegetable foods?

24. How does milk at 6 cents per quart compare in value with rump beef at 14 cents per pound?

25. What is the principal reason for using butter on bread?

26. How does cheese at 16 cents per pound compare in economy with meat at the same price?

27. Is it necessary that eggs be perfectly fresh and not case eggs in order to be wholesome?

28. What are the principal reasons for using fruit in the diet?

29. Are soup greens economical? What might be used in their place?

30. Which is most economical as a source of fat, — lard, suet, or butter?

Special Reports

1. The necessity for a mixed diet.
2. Common errors in diet.
3. Proper methods in cooking foods.
4. Work of the United States government in determining the nutritive value of foods.
5. The value of eggs as food.
6. Some foods that would make a satisfactory dinner at small cost.
7. The use of milk as food.
8. The use of soups as food.
9. Some commonly used expensive foods and how to get along without them.
10. The necessity for food.
11. The comparative cost and value of corn meal, sirloin steak, codfish, and oysters as food.
12. Show how 10 cents' worth of corn meal will equal $2 worth of oysters. How 10 cents' worth of stewing beef is equal in value to 25 cents' worth of sirloin.
13. The value of peas, beans, and other legumes as food.
14. Fish as food.
15. The composition and cooking of meats.
16. How to live on a small income.
17. The use of the microscope in food adulteration.
18. The fireless cooker and its uses.
19. Poultry as food.
20. Human foods and their nutritive value.
21. Sugar as food.
22. The preparation of vegetables for the table.
23. Practical sanitary and economic cooking.
24. Nutritive value and costs of foods.
25. Try expanding the following paragraphs as special reports. (Choose one.)

a. "The ideal diet is that combination of foods which, while imposing the least burden on the body, supplies it with exactly sufficient material to meet its wants."

b. "Too much food is as bad as too little and occasions a waste of energy and strength in the body as well as a waste of nutritive material."

c. "In ordinary mixed diet the chief sources of proteid are meat, fish, and milk among animal foods, and the cereals and legumes among vegetable foods. Beans, peas, and oatmeal are rich in proteid and hence especially valuable foods. About nine tenths of the fat in the ordinary

diet is obtained from the animal foods, while the vegetable foods furnish approximately nine tenths of the carbohydrates."

d. "The common or average American family wastes as much food as a French family would live upon."

e. "We live not upon what we eat, but upon what we digest."

f. "As many lives are cut short by unhealthful food and diet as through strong drink."

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SUMMARY I

A summary of some food values.[1]

DIETARY CALCULATION WITH FOOD VALUES IN CALORIES PER OUNCE

BREAKFAST	PROTEIDS	FATS	CARBOHYDRATES	TOTAL
Gluten Gruel, 5 oz. . .	23.5	1	30	
Soft-boiled Egg	26.3	41.9		
Malt Honey, 1 oz. . . .			86.2	
Creamed Potatoes, 5 oz. .	15	40	104	
Zwieback, 2 oz.	22.8	52.8	171.6	
Pecans, $\frac{3}{4}$ oz..	8.4	141	13.4	
Apple, 5 oz.	2.5	6.5	83	
	98.5	283.2	488.2	869.9

DIETARY CALCULATION WITH FOOD SERVED IN 100 CALORIES PORTIONS

DINNER	PORTIONS IN SERVING	PROTEIDS	FAT	CARBO-HYDRATES	TOTAL
Nut French Soup .	$\frac{1}{2}$	10	20	20	
Nuttolene Sauce .	1	29	55	16	
Macaroni, Egg . .	1	15	59	26	
Baked Potato . .	2	22	2	176	
Cream Gravy . .	$\frac{1}{2}$	5	33	12	
Granose Biscuit .	$1\frac{1}{2}$	20	2	128	
Butter	1	1	99		
Malt Honey . .	2			200	
Celery	$\frac{1}{4}$	4		21	
Apple Juice . . .	$\frac{1}{2}$			50	
	$10\frac{1}{4}$	106	270	649	1,025

[1] Courtesy of American School of Home Economics, Chicago.

HOURLY OUTGO IN HEAT AND ENERGY FROM THE HUMAN BODY AS DETERMINED IN THE RESPIRATION CALORIMETER BY THE UNITED STATES DEPARTMENT OF AGRICULTURE.

Average (154 lbs.)	CALORIES
Man at rest (asleep)	65
Sitting up (awake)	100
Light exercise	170
Moderate exercise	190
Severe exercise	450
Very severe exercise	600

PROBLEM XLIII

A study of some forms of food adulteration, and some simple means of detecting them.

a. Definition

Note. — Foods are said to be *adulterated* when any substance is added to them which *does not properly form a part of the food.* Such foods are not necessarily unwholesome. This study was first taken up in this country in 1881. The first food inspection law was enacted here in 1883, in Massachusetts. More than twenty-five states are now attempting to regulate the character and quality of foods sold in the market.

Note. — Starch is sometimes added to sausage to increase its weight, or permit of a larger amount of water or fat meat. If sold as pure sausage, it would clearly not be in any sense poisonous, but should be labeled "misbranded," and is evidently a fraud. Why?

b. Chemical Preservation

Note. — Such substances as benzoic and boric acids, borax, formaldehyde, and sulphurous acid are used. (Show specimens.)

c. Coloring Matter

1. Used in cheaper grades of jellies, to imitate good grades; therefore a fraud.
2. Used in tomato catsup, and canned tomatoes.
3. Used to make cucumber pickles greener (copper).

4. Used to make peas and beans greener (copper).
5. Used to color poor butter.
6. Added to chopped meats, sausage, etc., to give fresh color.

d. Some Simple Tests

1. Put some chloroform in tomato catsup or other table sauces and shake it vigorously, pour it off into a saucer and let it stand until it evaporates. If crystals are left, they are probably benzoic acid.

2. Put a teaspoonful of milk in a teacup, with twice the amount of HCl to which has been added a drop of ferric chloride. Mix them by rotating the cup gently. Put the cup in a vessel of boiling water and let it stand for 5 minutes. If formaldehyde is present, it will be shown by *purple* or *lavender color.*

3. Mash some canned peas or string beans with a spoon. Put a teaspoonful of it in a teacup with 3 teaspoonfuls of water and 30 drops of HCl. Set the cup in a pan of boiling water. Drop a bright iron nail into the cup and keep the water boiling for a few minutes, stirring the mixture frequently; if copper is present, it will plate the nail *copper color.*

4. (*a*) Stew $\frac{1}{4}$ teaspoonful of ground coffee in one half cup of boiling water and cool. Dilute with water, if it is dark colored, and add iodine solution drop by drop. Color? Conclusion?

(*b*) Same for ground cloves, mustard, cayenne, etc.

(*c*) Add a teaspoonful of finely ground coffee to one half glass of cold water. Pure coffee will float, and its adulterants, chickory, roasted cereals, etc., will sink. Pure coffee will not appreciably color the water, while chicory will leave a brownish trail as it sinks. Limit test to 5 minutes.

5. Place a tablespoonful of tea in a wide-mouthed bottle and shake it with six times its volume of cold water. Strain the water through a sieve and any insoluble mineral substances used on the leaves will settle.

6 Put some butter or oleomargarine in a spoon and heat over a lamp. If it is fresh butter it will boil *quietly* with *much*

foam. Oleomargarine or poor butter will sputter and crackle like a green stick burning, and with little foam.

7. Add 2 or 3 tablespoonfuls of Halphen's solution[1] to an equal amount of *salad oil* and heat the mixture in a vessel of boiling salt solution, for 10 or 15 minutes. A reddish color indicates *cottonseed oil.*

8. (*a*) Hold an egg between the eye and the light by putting it at end of a tube and looking toward a bright light. Presence of dark spots shows that the egg is not perfectly fresh; absence of air cell at one end shows the same. In eggs long packed, the yolk or the white slightly *adheres* also, or the egg will adhere to the shell on one side and also have a musty odor.

(*b*) *Another test.* — Make a weak salt solution of about 10%. If the eggs float in it, they are not fresh.

9. Rinse out a glass with small amount of vinegar and allow to stand a number of hours or over night. If the vinegar was made of wine, there will be a wine odor left in glass; if of apples, then a fruity odor.

10. Place a teaspoonful of lemon or orange extract in a test tube and add 2 or 3 drops of hydrochloric acid. No change indicates natural color, turmeric, or naphthol orange (harmless); pink indicates tropæolin or methyl orange; partial decoloration, Martius yellow; complete decoloration, dinitro cresols.

e. Table Waters

Note. — $12,000,000 of bottled water sold to public and more than $1,000,000 imported each year. Most carbonated waters receive their sparkle through artificial treatment by adding the gas of soda water or "vichy."

Questions

1. What are the pure food laws of your state?
2. Do the pure food laws of your state protect you from adulterated foods shipped in from other states?

[1] Halphen's solution is made by dissolving ⅛ teaspoonful of flowers of sulphur in some bisulphide of carbon; mix this with an equal volume of *amyl alcohol.*

3. Should there be a uniform pure food law for all states? Give your reasons.

4. When are foods said to be adulterated?

5. How can you tell good butter from poor? From oleomargarine?

6. How may foods be adulterated? Name some adulterants.

7. How can you detect the presence of formalin in milk?

8. How find out whether copper is used to give a green to pickles, etc.?

9. How find out whether sausages are adulterated? Coffee? Pepper? Tea?

10. How distinguish olive oil from cottonseed oil?

Special Reports

1. The pure food laws.
2. Deleterious ingredients in foods.
3. Pure milk and the public health.
4. Try to justify the following statement: "Ten billions of dollars are expended annually in the United States for food, clothing, and shelter. With greater knowledge and efficiency, better satisfaction could be obtained and one billion dollars be saved for higher things."

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PROBLEM XLIV

A study of some medical frauds.[1]

I. NOSTRUMS

a. The Bracers

Note. — "Gullible America will this year spend some $75,000,000 on patent medicines and incidentally with them swallow huge quantities of alcohol, much opiates and narcotics, and be most scandalously humbugged."

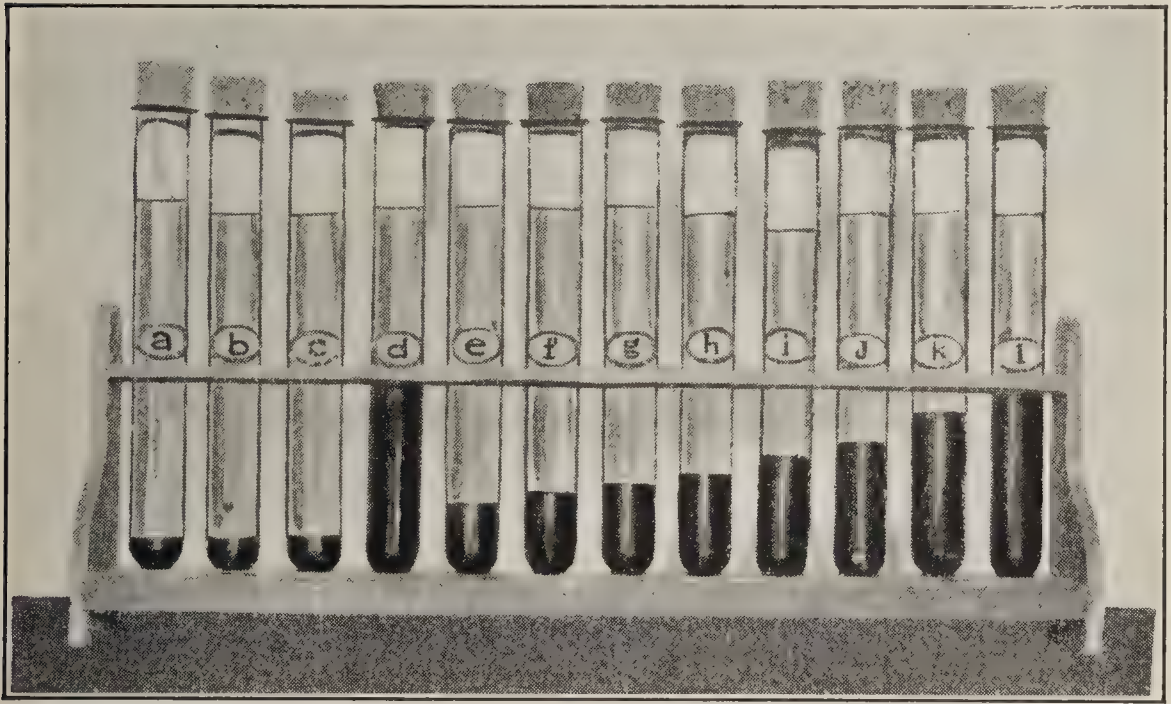

Fig. 59. — Showing percentage of alcohol in certain liquors and patent medicines. A test tube represents a glass. *a*, beer, 5%; *b*, claret, 8%; *c*, champagne, 9%; *d*, whisky, 50%; *e*, well-known sarsaparilla, 18%; *f*, much-advertised vegetable compound, 20%; *g*, celery compound, 21%; *h*, popular blood bitters, 25%; *i*, another sarsaparilla, 26%; *j*, tonic, 28%; *k*, another brand of bitters, 37%; *l*, another bitters, 44%.

Observations. — 1. Note the percentage of alcohol in the following patent medicines by comparing the test tubes. *Note.* — The tubes should be filled with water or alcohol to the indicated heights and the contents colored with carmine to make

[1] Adapted from Adams, *The Great American Fraud*, American Medical Association, Chicago.

them more of an object lesson. Let each one represent a glass of the compound considered.

2. How much alcohol in tonic *j* (Fig. 59), as compared with a bottle of beer of the same size?

3. How many bottles of champagne or claret will equal the alcohol value of one bottle of tonic *j* (Fig. 59)?

4. How much beer would a toper need in order to equal in alcohol value one bottle of bitters *l* (Fig. 59)?

5. Get the names of as many patent medicines as you can at drug stores, such as "spring tonics," "invigorators," "swamp roots," "nerve builders," "bitters," etc.

Conclusion. — Can you decide why most of the above might have a decided "tonic" effect for a short time? *Note.* — Most patent medicines cure by faith and the stimulus of the contained alcohol or opiates. Explain how the effect of these medicines might cause most people to write glowing testimonials.

b. Ozone Preparations (Optional)

Note. — These and similar preparations are being put on the market in answer to a demand for something to kill disease germs. The public mind blames germs for *all* diseases.

Observations. — 1. Get the names of as many patent medicines as claim to cure all such germ diseases as asthma, bronchitis, hay fever, tuberculosis, fevers, etc.

2. Look up ozone and its properties. (See any good text in chemistry, or a dictionary.)

3. What do these medicines profess to cure? *Note.* — Notice that the list includes (1) all diseases that begin with fever; (2) all catarrh; (3) all contagious diseases; (4) all inflammation; (5) all the results of impure and poisoned blood.

4. What is the taste of the so-called ozone compounds? *Note.* — The taste indicates the presence of an acid.

5. Warm some of one of these compounds with HCl. Is there an odor something like that from burning sulphur matches? Are there bubbles given off? Wet a piece of filter paper with a potassium bichromate solution and expose to the escaping fumes. Does it turn the paper green? *Note.* — A green color shows the presence of sulphurous acid.

Study the analysis of one of them, which follows : —

Sulphuric acid	$\frac{9}{10}$ of 1 %.
Sulphurous acid	$\frac{3}{10}$ of 1 %.
Water	about 99 %.

Note. — Sulphuric acid is oil of vitriol. Sulphurous acid is much like it. Both are poisons.

Conclusions. — 1. What have you learned about the composition of this compound ?

2. Do you think that it is necessary to buy such patent medicines ? *Note.* — Their acids are known to be positively injurious to health.

3. Find out the cost of the ingredients given in the analysis. Also the cost of a bottle of the medicine as sold at the drug store. How much profit is there on the original cost ? Who gets most of it ?

4. Guinea pigs were treated with one of these compounds, and they died, in varying periods of time. (See report of Lederle Laboratories, 518 5th Avenue, New York, of October 21, 1905.) What does that indicate as to its probable effect on other similar animals and even man ?

5. Why have such states and communities as North Dakota, San Francisco, and Lexington, Ky., forbidden their sale ?

c. The Subtle Poisons

1. Headache and Neuralgia Cures

Note. — Most headache powders depend for their action on the presence of *acetanalide.* Acetanalide depresses heart action, and many deaths are directly charged to its use in various antipain preparations.

Observations. — 1. Place a small quantity of a headache powder in a dry test tube with a like amount of zinc chloride. Heat it slowly until fumes arise. Hold a wood splint in its fumes. Is the splint colored by the fumes ? *Note.* — The presence of a *red or yellow color, or both, indicates the presence of acetanalide, a substance unsafe to take without the advice of a physician.*

2. Test as many other alleged headache powders as possible for acetanalide.

Note. — If any of the powders do not respond to the test for acetanalide, they should be tested for other dangerous drugs.

3. Test some of the advertised quinine tablets in the same way.

4. Get a list of all the "headache cures," antipain, and neuralgia cures you can.

5. List the different troubles that a headache powder claims to cure.

6. Are there any sample medicines being distributed in your neighborhood?

Conclusions. — 1. Write a paragraph or so, telling what you have learned regarding most so-called headache cures.

2. Why is one of these compounds called "a good repeater"?

3. What is the general reason for distributing such sample medicines?

2. Catarrh and Other Cures

Observations. — 1. Many antipain catarrh remedies and soothing sirups contain opium or cocaine. Inquire the uses of such remedies as codein, laudanum, paregoric, soothing sirup, etc. *Note.* — Such remedies contain morphine, opium, or cocaine.

2. Get a list of as many so-called catarrh cures as possible and note their claims. *Note.* — Dozens of these catarrh cures have been tested, and are known to contain much cocaine.

3. Are there any "sample" medicines being distributed on the streets or otherwise in your neighborhood? If so, what are they?

4. Scan the daily papers for advertising matter concerning such remedies as the above. List the names of the remedies and the companies selling them. Which papers carry the most of such advertising?

Conclusions. — 1. Explain the statement credited to a New York woman concerning her two young children: "Just one teaspoonful of soothing sirup, an' they lay like dead till morning."

2. Why should shop girls and others be likely to call for Blank's Catarrh Cure?

3. Only when is it wise to take "patent" medicines of any sort?

4. What general reputation do the papers carrying the above advertisements bear?

3. Preying on the Incurable

Note.— Such diseases as consumption, cancer, dropsy, heart disease, deafness, epilepsy, fits, and paralysis are probably incurable by *medicines.*

Advertisers professing to cure these diseases with medicines are therefore virtually "birds of prey" and are preying on humanity.

Observations. — 1. Scan the daily papers for advertisements that profess to cure any of the above diseases.

2. Do such fakirs "guarantee" their remedies? List some that do.

3. What is malt whisky listed to cure?

4. Do any claim to "return your money if not satisfied"?

5. Can you find any offering to send medicines free?

6. Do any advertise "no cure, no pay"?

Conclusions. — 1. Why is it that people allow themselves to be humbugged into buying such remedies as listed above?

2. Why should state and government aid be asked in order to suppress such fraud?

3. What can you do to help?

4. What precautions should you think advisable if you were about to buy a house, an automobile, or even a pair of shoes? Would ordinary testimonials suffice?

5. Do people observe the same precautions when they set out to buy health?

II. QUACKS AND QUACKERY

a. Sure Cure School

Observations. — 1. Look for advertisements that profess to "cure where all others fail." Such are surely "quacks," and those who patronize them are scarcely better.

2. List as many firms as you can find who profess to be "sure cure."

3. Can you see any reason for the remark made by a member of a quack firm, "Keep 'em sick by suggestion"?

Conclusions. — 1. Should you be likely to patronize any physician who says he can "positively cure"?

2. What reasons can you give for *never* patronizing any firm through the mails?

3. Give your reasons for never patronizing any "secret remedies," also "no cure, no pay" firms.

4. What class of newspapers do you find advertising "specifics," "sure cures," etc.?

5. Why should such papers be classed also as quacks and certainly lacking in moral sense?

b. Miracle Workers

Observations. — 1. Look up and list all firms claiming to cure by (1) "Magnetic healing," (2) "Healers," (3) "Radiotherapy," (4) "Vibrations," (5) "Magnetic Belts," (6) "Magnetic Shields," (7) "Health Homes," (8) "Supernatural Power," etc.

2. Tabulate the above, showing just what firms so advertise and what they claim to cure, thus: —

	1	2	3	4	5	6	7	8	9	Others	
Firms . . .											
Diseases they claim to cure . .											

Conclusions. — 1. Who are most susceptible to such advertisements?

2. Show that there is truth in Barnum's statement that "The American people like to be humbugged."

3. Why do "miracle workers" usually not remain in one place long at a time?

c. The Specialist Humbugs

Note. — "Specialist humbugs" diagnose by mail and send doses by express. They "consult" by a series of ingenious letter forms.

Observations. — 1. Look for such advertisements as "Don't undergo an operation, come to me and spare yourself the torture of the knife," etc.

2. Do any claim to "continue the treatment after a few months free of charge"?

3. Do any claim to cure by "absorption methods"?

4. Do any claim to be "editorially indorsed," or backed by any "religious paper," or claim a "special interest" in your case at "reduced rates"?

Note. — If you come across any such statements as just quoted, you may be sure they are quacks.

5. Do they address you as "Dear Friend" or "Dear Mr. So-and-so" or "My Dear Correspondent" in answer to any letters? If so, and you are determined to give them a trial, answer that, since a promise is made to cure you, you will deposit in a reputable bank the full price of the treatment, to be paid as soon as the promises are fulfilled, *and not before.* What reply do you receive?

Conclusions. — Write a paragraph on the methods of humbug specialists and how to distinguish them.

d. The Scavengers

Note. — By scavengers, we may perhaps rightfully designate all who claim to cure various diseases, including the drink and the drug habit, by mail.

Observations. — 1. Look for any advertising matter coming under the above headings. Just what do they profess to do?

2. Do they attempt to get the indorsement of prominent people?

3. Do any pretend to be physicians?

4. Write the nearest drink cure company. What do they profess to do? *Note.* — Any such companies not professing to certainly cure, especially "where all others fail," or take pay for cases they know to be incurable, may be classed as reputable and quite likely doing good work.

5. Do any firms profess to send treatment by mail C.O.D.?

6. Do any profess to be "strictly confidential"?

7. Do any states forbid advertising of this sort? *Note.* — Some communities have passed such laws, but they have been largely a farce, as some temperance laws have been. In other words, many people do not realize how scandalously they are being humbugged, and patronize the "scavenger" type of firms by stealth. If all communities or states would coöperate, and the moral sense of the people were aroused through education, a much different story might be told.

Conclusions. — 1. Show why government aid should be invoked in dealing with such advertisers as considered under this section.

2. Write a paragraph telling how you would recognize fakirs designated as "scavengers."

Questions

1. Why are some patent medicines well called "bracers."

2. Why are some patent medicines best known as "repeaters"?

3. What effect has acetanalide on the heart? In what medicines is it likely to be found? How detect it?

4. Are "strictly confidential" firms of good repute? Explain.

5. What conclusion is evident whenever you see advertisements with photographs of "cured" people inserted?

6. How distinguish "specialist" humbugs from "scavengers"?

7. Name some "habit-forming" agents. Why is their indiscriminate sale and use a menace to the public welfare?

8. Show how the following is true: "Most illness results from carelessness, ignorance, or intemperance of some kind."

Special Reports

1. The great American fraud.
2. The specialist humbugs.
3. The scavengers.
4. The "sure cure" school.
5. Harmfulness of headache mixtures.
6. Some "habit-forming" agents.

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SUMMARY II

A summary of stimulants and narcotics, with some reference to patent medicines.

Note. — None are necessary to enable one to make the greatest success in life.

I. NARCOTICS

(Relieve pain, and tend to produce sleep.)

1. Tobacco.
   a. Has nicotine, — a poison. Harms by irritating and may tend to produce ulcer of the mouth, hoarseness, and throat troubles. May impair digestion. Affects the heart beat. Cigarettes impair physical health and mental vigor. Out of 100 boys in New York city charged with crime 99 are cigarette smokers.
2. Opium.
   a. From juice of poppy. Sleep-producing.
      1. Paregoric equals opium, alcohol, camphor, and other drugs.
      2. Laudanum equals opium, alcohol, and water.
3. Morphine.
   a. From opium, and four times as strong as opium. Neither should be taken except by advice of a physician.
4. Many Patent Medicines.
   a. Many contain much alcohol. The sick think they help because of the stimulating effect of the alcohol at the time.
   b. Soothing sirups contain opiates.
   c. Many remedies for colds and catarrh contain opium, morphine, and cocaine.

II. STIMULANTS

(Cause organs to act more vigorously.)

1. Tea.
   a. Black tea the best. Made by pouring boiling water on the leaves and pouring off the infusion.
   May produce dyspepsia and nervous disorders.
2. Coffee.
   a. Stimulates the brain and heart, and may disturb digestion and produce nervousness and sleeplessness.
3. Alcohol.
   a. Thirst for this affects over 1,000,000 of our people. May produce a bad habit and wreck both body and character.

III. ALCOHOL (Special)

(General effect to produce *poverty* and *crime*.)

1. Amount in Liquors.
   a. 3–12%.
      Beer, stout, porter, ale, champagne, cider, etc.
   b. 15 to 20%.
      Sherry, gin, port wine, and many patent medicines. ($75,000,000 worth of patent medicines contain alcohol.)
   c. 55%.
      Whisky.
2. Amount Consumed.
   a. Beer, 1,000,000,000 gallons. (Requiring 60,000,000 bushels of grain,— a great loss.)
   b. Wine, 2,000,000 gallons.
   c. Whisky, 4,000,000 gallons.
3. Alcohol in Health.
   a. Has no good effect.
   b. Weakens instead of strengthens.
   c. Weakens digestion, and decreases value of food consumed.
4. Alcohol and Disease.
   a. Affects liver, kidneys, heart, blood vessels, and nervous system.
   b. Said to cause Bright's disease, gout, heart disease, and catarrh, and weakens the white corpuscles, or those cells that naturally fight off pneumonia, tuberculosis, etc.
5. National Loss through Liquor. (One thousand arrests per day through drunkenness, and one half the number of destitute children made so by alcohol.)
   a. Ruins homes, bodies, and character.
   b. Ten thousand of our convicts victims from its use, and 30% of the inmates of almshouses.
   c. Courts disease, suffering, and death.
   d. Money loss per year at least $1,200,000,000.
      Gladstone said: "Alcohol is productive of greater evils

than the combined scourges of war, famine, and pestilence."

6. Alcohol as a Medicine.
   a. It has never been known to *cure* any disease, but may *help* to do so.
7. Called a Poison (as it causes sickness and death when introduced into the body).
   a. Destroys will power.
   b. May affect the internal organs.
8. Dangers from its Use.
   a. Weakens body and mind, thus making men more liable to disease and crime.
   b. At least one in 10 occasional drinkers become intemperate.
   c. Affects tissues of the young more than those of the adult, or past 30 years.
   (No greater patriotism can be displayed than to fight this evil, and nothing requires greater courage.)

ADAPTATIONS FOR DIGESTION, CIRCULATION, AND ABSORPTION OF FOOD

PROBLEM XLV

To study the digestive system of a frog, in order better to understand that of man.

Materials. — Frogs preserved in 4% formalin. Some with ventral body wall removed, others for optional dissection by the pupil. Split specimens of frogs' stomachs. Portable microscope. Chart showing digestive system of frog.

a. General Study and Adaptations

Observations. — 1. Note the looseness of the skin. Are the muscles forming most of the ventral body wall thick or thin?

2. Find a large, reddish brown, lobed organ (*liver*) which nearly covers the other organs. How many lobes has the liver?

3. Lift the liver to one side, and find a small greenish body (*bile sac* or *gall bladder*) on one side of the liver and between its lobes. To what does it seem to be attached?

4. Open the mouth of the frog and force a small probe down its throat into its continuation (the *gullet* or *esophagus*). This leads to an enlargement (*stomach*) which in turn leads to a long slender tube (*small intestine*).

5. Look for a thin membrane (*mesentery*) holding the coils of the small intestine in place. Is it along the full length of the small intestine?

6. Note that the small intestine leads into a larger tube

(*large intestine*) which empties into the cloaca. How does the large intestine compare in length with the small intestine?

7. Look between the stomach and first bend of the small intestine and find a yellowish body (*pancreas*). Where does it seem to be attached?

8. Examine the split stomach and find folds and ridges of the inner wall. In what direction do they run, lengthwise or circularly?

9. Examine a mounted section of the small intestine of a cat or a dog through the compound microscope, and note the small elevations of its inner wall or lining, called *villi*. Describe the appearance of a villus.

Conclusions. — 1. Name the digestive organs in order, beginning in the mouth, and including all glands.

2. What advantage do you think there is in having the small intestine coiled? Why not the large intestine coiled? (See Absorption, in any advanced Physiology, or the instructor may mention it here.)

3. Do the ridges of the stomach affect its absorbing area in any way? Can you suggest any use of the villi of the small intestine?

4. Can you suggest any use for the mesentery, other than support of the intestine?

5. What are the more important adaptations of the alimentary canal for the digestion of food? For the absorption of food?

b. Drawing (Optional)

Sketch the food tube, extended so it will show.

c. Comparison with Man

Materials. — Charts and manikins of man, showing the digestive organs, or Figure 60. Set of teeth. Piece of tripe.

Observations. — 1. Compare the digestive organs of the frog with those of man. What organs are similar? What organs present in man are not found in the frog?

2. Study a piece of tripe. What is tripe? What advantage in the "honeycomb" arrangement?

3. Why does a man need teeth? Are they all of the same shape?

4. (*Home work.*) With the aid of a small mirror count the teeth of each jaw. Answer the following questions:—

a. The total number on each jaw?

b. The number of broad teeth (*incisors*) in the front of each jaw?

c. The number with one point on the biting edge (*canines*)?

d. The number with two points on the biting edge (*premolars* or *bicuspids*)?

e. The number with more than two biting points (*molars*)?

f. Compare your results with Figure 61. How do they agree? Differ?

g. Examine the teeth of a cat or a dog. What difference do you find as to the kind and number of teeth? What kind of food do they eat?

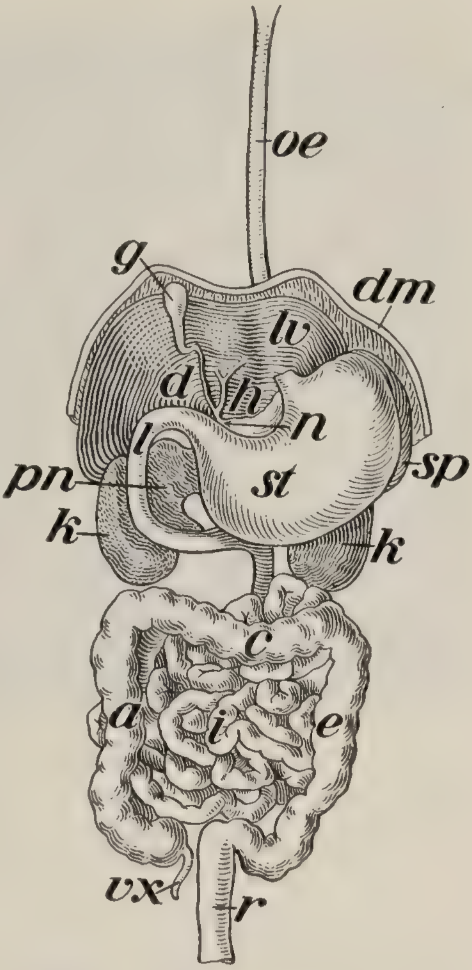

FIG. 60.—Front view of the organs of digestion of man. *a*, *c*, *e*, colon; *d*, duct of the gall bladder; *dm*, diaphragm; *g*, gall bladder; *h*, hepatic duct from the liver; *k*, kidney; *l*, *i*, small intestine; *lv*, liver; *n*, opening of the bile duct into the small intestine; *oe*, esophagus; *pn*, pancreas; *r*, rectum; *st*, stomach; *sp*, spleen; *vx*, vermiform appendix.

Conclusions.—1. Is there any connection between the food and the kind of teeth found in any animal?

2. What is the use of the teeth?

3. Why is thorough chewing a necessary first step in digestion?

4. Through what organs does the food pass in the course of its passage through the body of man?

Questions

1. What is meant by Fletcherism?
2. Why is it advisable that the teeth be examined by a dentist at least twice a year?
3. What are some of the causes of indigestion?
4. Why is regularity in eating of importance?
5. What causes teeth to decay?
6. Why should the teeth be brushed often?
7. Which of the human teeth are fitted for cutting? For tearing? For grinding?
8. Examine your own teeth and report just what teeth are present, what are missing, and whether any are coming in out of place. Write a report as home work and bring it to the laboratory.

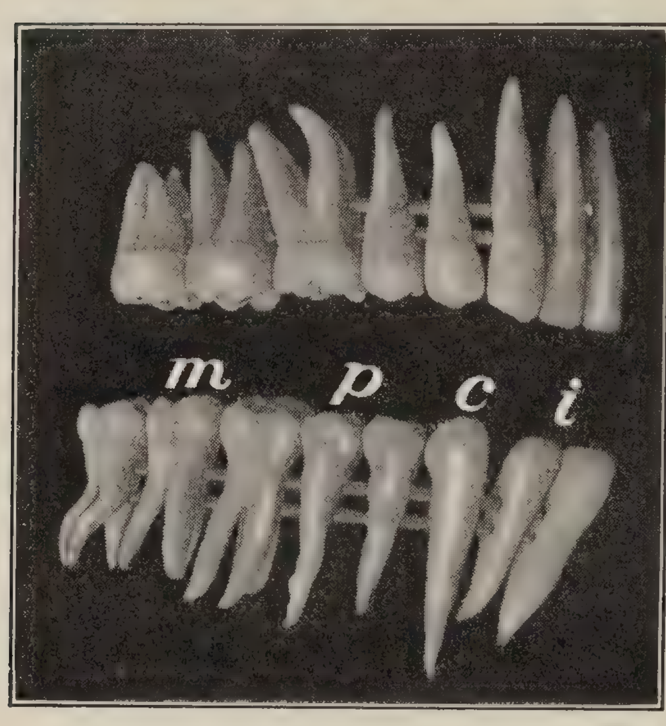

FIG. 61. — Mounted set of adult teeth. Right side. *i*, incisors; *c*, canine; *p*, premolars, *m*, molars. (Photograph by Davison.)

9. What glands furnish digestive juices?
10. What are the two parts of the trunk cavity in man? How are they separated?

SUMMARY III

A summary of the digestive system of man.

A. PARTS.

1. Alimentary canal.
   a. Mouth.
      (1) Tongue. Teeth. Kinds, structure and care of.
   b. Pharynx.
   c. Esophagus.

d. Stomach.

e. Intestines. Small and large.

2. Assisting glands.

a. Uses.

(1) To secrete juices for softening and dissolving food so that it may be absorbed into the blood by osmosis.

b. Kinds.

(1) Salivary furnish ------------------------------

(2) Gastric furnish ------------------------------

(3) Pancreatic furnish ------------------------------

(4) Liver furnishes ------------------------------

(5) Intestinal furnish ------------------------------

B. Extra.

1. Special functions of the liver.

a. A gland to secrete ------------------

b. A storehouse of ------------------

c. A guardian to destroy --------------- that otherwise might enter the blood.

PROBLEM XLVI

How foods are chemically prepared for absorption into the blood.

a. In the Mouth

1. Action of Saliva

Materials. — Cornstarch paste, grape sugar (glucose), saliva, test tubes, Fehling's solution, alcohol lamp or Bunsen burner, paraffin wax.

Method a. — Put some cornstarch in a test tube of cold water and shake it. Heat it until it boils. Set it aside to cool.

Observations. — 1. Does the starch seem to dissolve in the cold water? Its color?

2. Has the starch that was boiled disappeared from view, or dissolved, or is it still seen?

Conclusion. — Is starch soluble in cold water? In hot water?

Method b. — Put some grape sugar in a test tube with water and boil it. Add Fehling's solution and boil it.

Observations. — 1. Does the grape sugar dissolve in water?

2. What color is produced by boiling when Fehling's solution is added?

Conclusions. — 1. How determine whether grape sugar dissolves in water?

2. Review the test for the presence of grape sugar.

Method c. — Add some fresh saliva[1] to a small amount ($\frac{1}{3}$ test tube full) of diluted starch paste. Set it aside in a warm place, for ten minutes or more. Then test for grape sugar.[2] Test some of the saliva for grape sugar and likewise test the starch paste.

Observations. — 1. What effect when Fehling's solution and saliva are boiled?

2. What effect when starch paste and Fehling's solution are boiled?

3. What effect when the mixture of starch paste and saliva are boiled with Fehling's solution?

Conclusions. — 1. Is there any grape sugar present in the saliva? Is there any grape sugar present in the starch paste?

2. Is there any grape sugar in the mixture of starch paste and saliva after standing for a short time?

3. How can you account for the sugar in the starch paste after treating it with saliva?

4. What is the effect upon the solubility of starch after treating it with saliva?

5. What is digestion?

6. Chew a piece of cracker slowly. Can you account for the sweetish taste? (Home work.)

b. In the Stomach

1. Action of Gastric Juice (Optional)

Materials. — Minced white of boiled egg, hydrochloric acid, pepsin, 5 numbered test tubes, beaker, and cracked ice in a container.

[1] Fresh saliva may be procured by first rinsing the mouth, then chewing Paraffin wax and collecting the saliva in a test tube.

[2] The sugar present is really maltose. The tests for the two sugars are the same.

Method. — In No. 1 place minced white of egg + water. In No. 2 minced white of egg +.2% HCL. In No. 3 minced white of egg + .2% HCl + pepsin. Numbers 4 and 5 as No. 3. Place Nos. 1, 2, and 3 near the register or radiator, or in a water bath, so as to keep them at about blood heat for a few hours. Place No. 4 in a vessel surrounded with cracked ice, or in as cool a place as possible for a few hours. Place No. 5 in boiling water for 15 or 20 minutes, then set it aside with Nos. 1, 2, and 3.

Observation. — Test No. 1 with the biuret[1] test for presence of peptone. Result?

Conclusion. — What is your conclusion as to the action of water on proteid?

Observation. — Test No. 2 as No. 1 was tested. What do you observe?

Conclusion. — Does hydrochloric acid change proteid into a soluble state?

Observation. — Test No. 3 as you tested Nos. 1 and 2. What do you observe?

Conclusions. — 1. What is your conclusion as to the effect of HCl + pepsin on proteid?

2. Is the resulting substance soluble or insoluble?

Note. — If the proteid has been made soluble by the action of pepsin, it is because it has been made into a soluble substance known as peptone.

Observation. — Test Nos. 4 and 5 as Nos. 1, 2, and 3 were tested. What do you observe?

Conclusions. — 1. What are your conclusions as to the effects of high temperature and of low temperature on the action of pepsin on a proteid? Explain.

2. Write a connected account of all your conclusions here. Try tabulating your results.

c. In the Small Intestine

1. Action of Pancreatic Juice (Optional)

Materials. — Pancreatin, sodium carbonate or baking soda, starch, proteid, olive oil or butter, water bath.

Note. — Artificial pancreatic juice may be made by mixing 10 grains of pancreatin with 20 grains of baking soda and adding 200 cc. of water.

Method a. — Add some dilute starch paste to a test tube half full of

[1] Biuret Test. — Add caustic soda in concentrated solution. To this add a few drops of solution of copper sulphate. A rose-pink color shows the presence of peptones. Violet color indicates the presence of unchanged proteid.

artificial pancreatic juice. Keep it in a warm bath at about blood heat for a few hours. Then test with Fehling's solution.

Observation. — What is the result when the mixture is tested with Fehling's solution ?

Conclusion. — What is the action of pancreatic juice on starch ?

Method b. — Shake a little melted butter or olive oil in a test tube half full of artificial pancreatic juice. *Note.* — Shake some oil and water in a test tube. Add a few drops of ammonia, and shake vigorously again. The resulting milky colored *mixture* is called an *emulsion.* Where have you heard of it before ?

Observations. — 1. What is the appearance of the mixture ? *Note.* — The oil is now in small microscopic drops scattered throughout the water.

2. What is the result of shaking the oil or butter with pancreatic juice ?

Conclusion. — What is one result of the action of pancreatic juice on oils and fats ?

Method c. — Add some blue litmus solution to $\frac{1}{4}$ test tube of milk. Add some pancreatic juice and let the mixture stand in a warm bath at blood heat for a few hours.

Observation. — What is the final color of the mixture ?

Conclusion. — What has evidently been formed ? *Note.* — The fats and oils are finally split into glycerin and fatty acids and absorbed in this form.

Method d. — Add some proteid (minced white of egg) to a test tube half full of artificial pancreatic juice. Keep at blood heat for a few hours. Shake occasionally. Test for peptones as under study of gastric juice.

Observation. — What is the appearance of the contents of the tube ?

Conclusions. — 1. Is the egg digested ? Has any other digestive juice acted in the same way ?

2. Write a summary of your conclusions regarding the effect of pancreatic juice on nutrients.

2. Action of Bile (Optional)

Materials. — Ox gall or bile, olive oil, white of egg, pancreatic juice, test tubes.

Observations. — 1. Add some bile to minced white of egg in a test tube. Also to some starch. Results when kept in warm bath for a few hours ?

2. Add pancreatic juice to minced white of egg in two tubes. Add *bile* to *one* of the tubes. In which does digestion take place more quickly ?

3. Put proteid in two test tubes. Add bile to one. Let stand in warm place until putrefaction occurs.

Conclusions. — 1. Does bile digest proteid? Starch?
2. Does bile aid pancreatic juice?
3. Does bile prevent putrefaction?

Questions

1. What is a food? What is a perfect food?
2. Explain fully the digestion of a piece of bread and butter.
3. Soup is absorbed quickly. Why is it good to eat at the beginning of a meal?
4. Why is the chewing of tobacco and gum generally harmful?
5. In which of the digestive organs is but one kind of digestive juice furnished?
6. In what digestive organ are three juices poured?
7. What nutrient digested in only one organ?
8. What nutrients digested in two organs?
9. Why should starchy foods remain longer in the mouth than meat or proteid?
10. Why is half-cooked or soggy bread harder to digest than raw wheat? Which one needs the most saliva? Why?
11. For what purpose does the body use lean meat?
12. Name three foods easily digested. Three foods hard to digest.
13. The uses of starch or sugars in the body? Of fats?
14. Explain the biology of the following: —

"Now good digestion wait on appetite,
And health on both." — Shakespeare.

Special Reports

1. Common causes of illness.
2. Effect of lack of exercise on digestion.
3. Health fads and foods.
4. The harm done by ignorant cooks.
5. Effect of alcohol on digestion.
6. Causes and prevention of dyspepsia.

References

Hunter, *Essentials of Biology.* Chap. XXV.

Eddy, *Textbook in General Physiology and Anatomy.*

Davison, *The Human Body and Health.* Chap. VI.

"Influence of Food Preservatives and Artificial Colors on Food." Chemical Bulletin 84, Parts 2, 3, U. S. Department of Agriculture.

"The Waste of Overeating." *Success Magazine*, March, 1910.

Cantley, E., "Starch Digestion in Babies." *The Lancet*, 177, February, 1910.

Day, Edna E., "Digestibility of Starch as affected by Cooking." Bulletin 202, Experiment Station, Washington, D.C.

Fisher, *Physiology of Alimentation.*

SUMMARY IV

A summary of digestion.

1. Definition. The process of ____________ food, so that it may pass through the walls of the ____________ into the __________, and thence from the ___________ into the tissues to the cells.
2. Accomplished by,
   a. Mechanical means.
      (1) Chewing muscles. 2. Teeth.
   b. Chemical means.
      (1) Action of acids and alkalies on foods (bile, hydrochloric acid, etc.).
   c. Organic means.
      (1) Action of ferments.
         (*a*) Ptyalin in the mouth.
         (*b*) Pepsin in the stomach.
         (*c*) Pancreatic juice in the small intestine, etc.
3. Details of chemical and organic means.
   a. In mouth.
      (1) Saliva acts on ____________ to change it to ____________
      Food should be chewed on an average about _________ times, to well mix it with ____________. Good looks and taste of food start the flow of _________
      Chewing gum and tobacco wastes _____________
   b. In stomach.
      (1) Pepsin changes ____________ to ____________ which are ____________

------------- curdles milk. Soup for the first course of a dinner starts the flow of ----------- and temporarily satisfies the craving for food. This tends to prevent -----------

c. In the small intestine. (Nearly all digestion carried on here.)
   (1) Pancreatic juice acts on -----------
   (2) Bile aids in absorption of ------------
   (3) Intestinal juice acts on ------------

d. Large intestine.
   (1) Practically no digestion.

e. Fill in the following summary: —

Glands	Location	Juice	Enzymes or Ferments	Action of	Reason for its Action
1.					
2.					
3.					
4.					
5.					
6.					

PROBLEM XLVII

A study of where and how digested foods pass into the blood (absorption).

Materials. — Tripe, and charts showing the plan of absorption and the villi of the human intestine.

Note. — Observe how the mucous membrane of the small intestine is thrown into ridges and small elevations (villi).

a. The Villi

Observations. — Note the microscopic blood vessels (*capillaries*) entering a villus. If the liquid food is on the outside of the villus, how might it get inside the blood vessels?

Note. — The small blood vessels beginning here finally unite, and carry proteid, water, salts, and sugar to the liver.

Here may be also found the beginnings of other small tubes that carry emulsified fats and oils to a vein under the left collar bone. These small tubes are called *lymph capillaries.* As they carry emulsified fats and oils (for a time after meals) they are milky colored and are thus called *lacteals* (lac = milk).

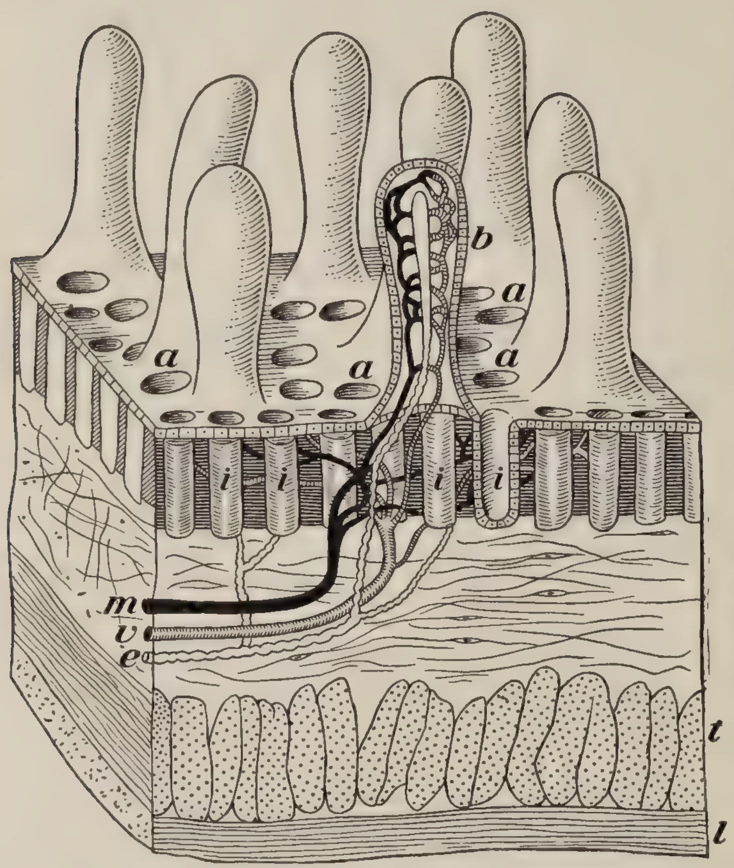

FIG. 62. — Diagram of the structure of a block of tissue smaller than a pin's head, cut from the wall of the small intestine. *a*, mouths of intestinal glands; *b*, villus cut lengthwise to show the blood capillaries and white lacteal within; *e*, lacteal vessel sending branches to many villi; *i*, intestinal glands; *m*, artery; *v*, vein; *l* and *t*, muscular coats.

Conclusion. — Show how the villi may be said to "lick up the digested food."

b. How Foods are Absorbed

Foods are absorbed into the blood vessels and lacteals of the villi of the intestinal tract,[1] and get into the circulation in the following ways:

1. Osmosis. Exchange through a moist membrane. Where have you heard of this before?
2. Filtration. Forced through by pressure when the muscular walls of the intestine contract.
3. Imbibition. About as a sponge absorbs water, or as a towel does the same.

[1] Nine tenths of the food that reaches the blood is absorbed by the villi of the small intestine. There are fully 20,000 villi to the square inch.

c. Paths of Absorbed Foods

Observations. — 1. The absorbed foods now take two different directions; all but the fats go at once to the liver, through the portal vein; while the fats are carried by the main lymph duct (*thoracic duct*) to a vein under the left collar bone as indicated above, therefore the fats do not pass directly through the liver but to the heart first. What are the lacteals? *Note.* — Study Figure 63 carefully, forming your own questions and answers.

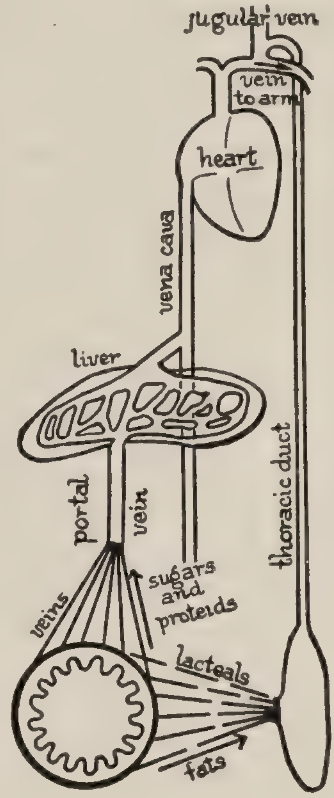

Fig. 63. — Diagram showing how the food reaches the heart to be sent with the blood to all parts of the body.

2. Fats are absorbed chiefly as fatty acids and glycerin. The cells of the villi reconstruct the fatty acids and glycerin into the microscopic fat particles which are passed on into the small tubes that finally converge to form, in part, the thoracic duct which conveys this fatty food into the general circulation.

3. The digestive tube is, then, a muscular tube of varying diameter, lined by mucous membrane. The muscular coat propels the foods and mixes them with the liquids present; some of these liquids merely soak the food, others act on it chemically, while mucus serves to lubricate the surface. It seems that the glands lining the inner surface of the digestive canal are not sufficient, so several extra glands are provided, such as the salivary glands, pancreas, and liver. Find these glands on a chart.

Conclusion. — Write a brief summary of the paths absorbed foods take in reaching the heart. Copy Figure 63.

d. Summary of Adaptions for Absorption

Fill in the following table: —

Foods	Where Absorbed	Form	Adaptations for	Path to Heart
1. Proteids .				
2. Sugars, etc.				
3.				
4.				
5.				

Questions

1. What are the uses of the lacteals?

2. What nutrients are digested and absorbed in only one organ?

3. Why must food be absorbed into the blood?

4. What is necessary before most foods can be absorbed?

5. What is the portal system? The thoracic duct?

6. Which of the following pass into the lacteals, and which into the capillaries of the portal vein — sugar, peptones, emulsified fats?

7. Name the organs of absorption in the small intestine.

8. Water and salt need no digestion. Why? Where are they absorbed?

9. Through what large tube is the fat carried in passing from the lacteals to the veins?

10. Where do the capillaries that take part in absorption empty?

11. What provision is made for storing sugar so that it will not pass suddenly to the cells after a meal, but be given to them gradually? *Note.* — Food is *assimilated*, or changed into living matter (protoplasm), in the cells.

12. What changes take place in the composition of the blood in the lining of the stomach? In the small intestine?

References

Hunter, *Essentials of Biology*. Chap. XXV.
Hunter, *Elements of Biology*. Chap. XXVIII.
Davison, *The Human Body and Health* (Advanced). pp. 98, 99, 108.

PROBLEM XLVIII

To study the general composition of blood.

Materials. — Fresh frog's blood or blood from the finger. Slides, cover glasses, portable compound microscope, or compound microscopes set in various parts of the laboratory for inspection by the pupils under direction of the instructor.

a. The Corpuscles

Note. — Observe that the blood is composed of two components, solid bodies (*corpuscles*) and a liquid (*plasma*). Some of the corpuscles are disklike, and some globular and granular, while the plasma is the liquid in which the corpuscles float.

Observations. — 1. What is the color of the corpuscles you most readily see? What is their shape? *Note.* — These are *red corpuscles.*

2. Do you find other corpuscles, — globular in shape and more transparent? (Difficult to see.) *Note.* — These are *white corpuscles.*

3. What is the appearance of the plasma?

Conclusions. — 1. Do you think that the functions of the two kinds of corpuscles are the same? That is, do special functions imply special structures?

2. Why does the blood appear red?

3. What have you already learned must be in the blood plasma?

4. What is an evident function of the plasma?

Questions

1. What service do the red corpuscles render? The white ones?

2. What is the use of fibrin?
3. What is serum?
4. What is the composition and use of blood plasma?
5. What is the function of plasma?
6. What are the chief functions of blood?

Special Reports

1. The work of the white corpuscles in destroying disease germs.
2. The necessity of a liquid medium for carrying supplies to the cells ("citizens") of the body, and for carrying away the waste.
3. The importance of coagulation.
4. The composition of the blood.
5. The life and work of Harvey.
6. The function of blood plasma.

References

Hunter, *Essentials of Biology*. Chap. XXVI.
Hunter, *Elements of Biology*. Chap. XXIX.

PROBLEM XLIX

A study of the circulation of the blood.

Materials. — Living frog, tadpole, or fish partly affected with ether, chloroform, or 1 % solution of chloretone, and mounted on a shingle having a ½-inch hole bored in one end, over which is placed the web of the hind leg of the frog or the thin part of the tadpole's tail or a fin of a fish. Keep the specimen wrapped in a moist cloth, and the part observed moist. Or use a chick embryo of 36 to 72 hours. Open the egg under a saline solution (.7 per cent NaCl at 38° C.). Remove the germinal disk with small dissecting scissors and float it out in a watch glass. Use low power here, with both low and high powers as needed for the rest.

a. Living Specimen

Observations. — 1. Note a network of small tubes with moving disks, partly obscured in the frog by many dark-colored,

irregular pigment cells. If you find the blood moving in regular spurts in any of the tubes, note how often the "spurts" take place. (These tubes lead from the heart, and are called *arteries.*)

Fig. 64. — Capillary circulation in the web of a frog's foot; *a*, *b*, small veins; *d*, capillaries showing corpuscles following one another in single series; *c*, pigment cells in the skin.

2. Do the arteries remain of a uniform size? If not, what becomes of them as you trace in the direction the blood flows? (The tubes into which arteries divide are called *capillaries*, and connect the arteries with tubes called *veins* that commonly carry impure blood, and lead toward the heart.)

3. How does the blood flow in a vein differ from that in an artery?

4. Do you notice any disklike bodies (red corpuscles) in the blood? Are they numerous or few?

5. Look for minute colorless bodies (white corpuscles).

Conclusion. — Sum up your conclusions regarding the circula-

tion of the blood as shown on the web of a frog's foot, or tail of a tadpole, etc.

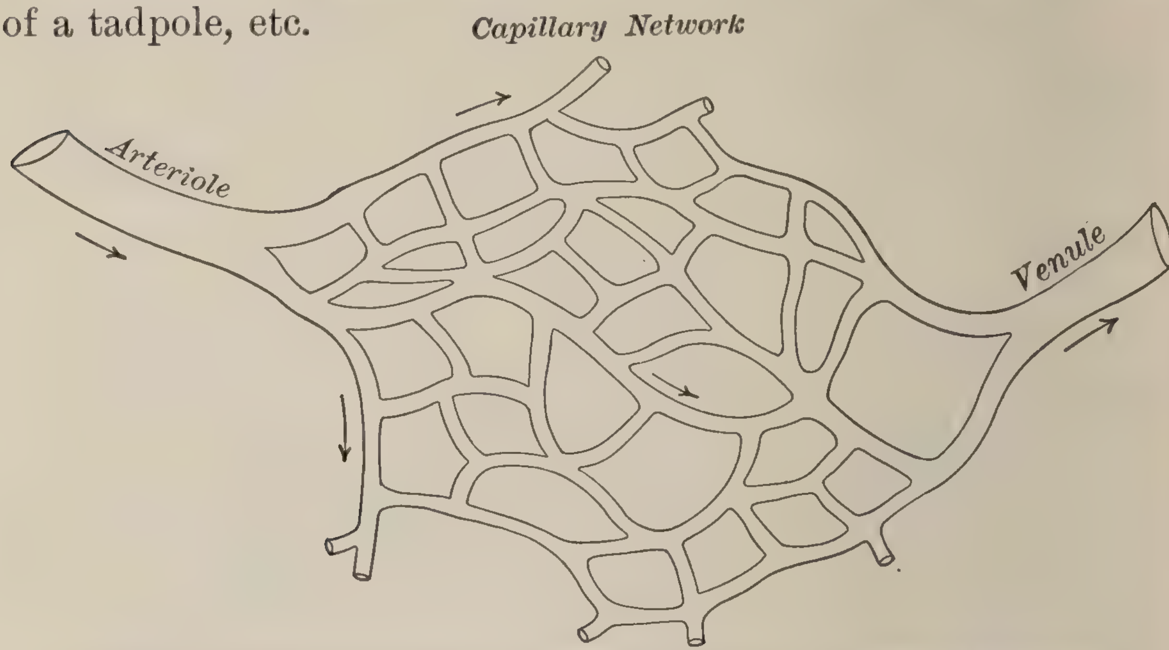

FIG. 65. — Capillary network, showing connection of arteries and veins.

b. Your Body

Method. — Place a finger of your right hand on the artery of the left wrist, just at the base of the thumb. Count the number of pulsations after you have been sitting quietly, after rising and again sitting, and after a little exercise or light gymnastics. (All stand for this phase of the exercise and try a "setting up" exercise for a half minute or so.)

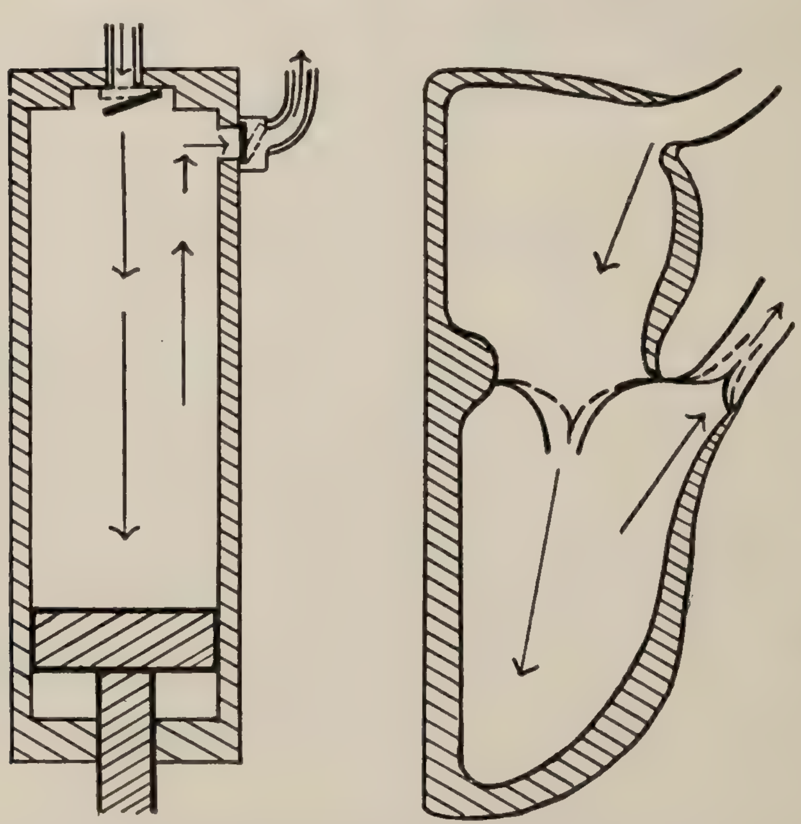

FIG. 66. — Diagram showing how the heart acts as a force pump.

Observation. — What is the pulse

beat per minute when quiet? What when lightly exercising? What when more vigorously exercising?

Conclusion. — Write out your conclusions as to the effect of exercise on the heart action and thus of the pulse.

Observation. — Press a vein in your wrist with one finger. On side of finger toward the heart empty the vein by just rubbing another finger along it. Does the blood flow back into the vein? Rub the blood away from the heart, on other side of finger pressing the vein. Does the blood flow back?

Conclusion. — What is your conclusion concerning the structure and direction of blood flow in the veins?

c. Study of Chart, and Sheep or Beef Heart

Method. — 1. Refer to any good chart of the circulation or to Figure 67 and find the heart, arteries, and veins. Also examine a sheep or beef heart or good model and note the four chambers, the valves, and the blood tubes connected to it.

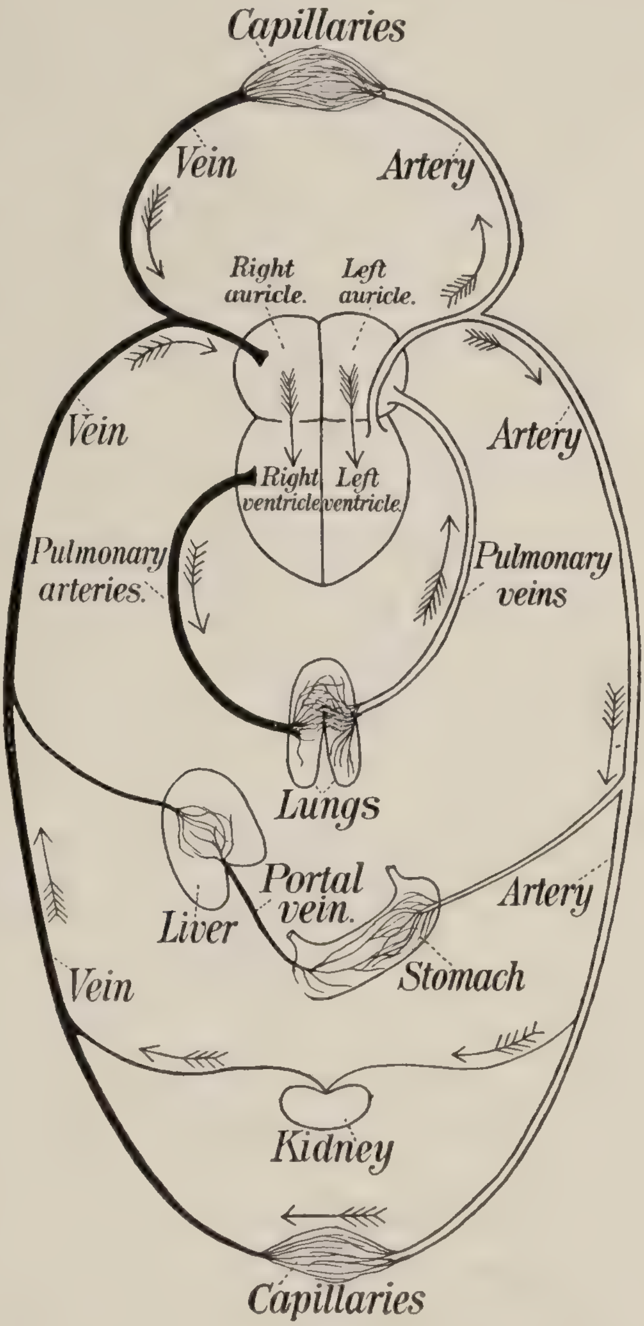

Fig. 67. — Plan of circulation of blood.

Observations. — 1. In what direction do arteries lead? Veins?

2. Can you make out the heart to be a double force pump? Study Figure 66.

3. Where does the right side of the heart send the blood? The left?

4. How do arteries end? Veins begin?

5. Do you find any special blood tubes running to the liver? *Note.* — Much digested food absorbed from the small intestine must pass through the liver before it reaches the heart. Many impurities are taken out in the liver.

Conclusion. — Trace the general circulation of the blood.

d. The Circulatory System

Observations. — 1. Try to fill in the following outline: —

I. General function of circulation.

II. Materials carried, their sources and destinations: —

Materials	Source	Destination
1		
2.		
3.		
4.		
5.		

III. Constituents of the blood, with their special functions (Report in tabular form.)

1. Plasma.
   a.
   b.
   c.
2. Corpuscles.
   a.
   b.

IV. The circulatory apparatus and functions.

1. The heart.

2. The blood vessels.

   a.

   b.

   c.

3. The lymph and lymph vessels.

V. The course of the circulation. (Represent it by means of a diagram.)

e. Use of a Tourniquet

Observations. — 1. Study Figure 68, in order to learn where best to apply a tourniquet. Practice making and applying one made of a ruler or stick, pocket handkerchief or towel, and a pebble or any such solid. See Figure 69.

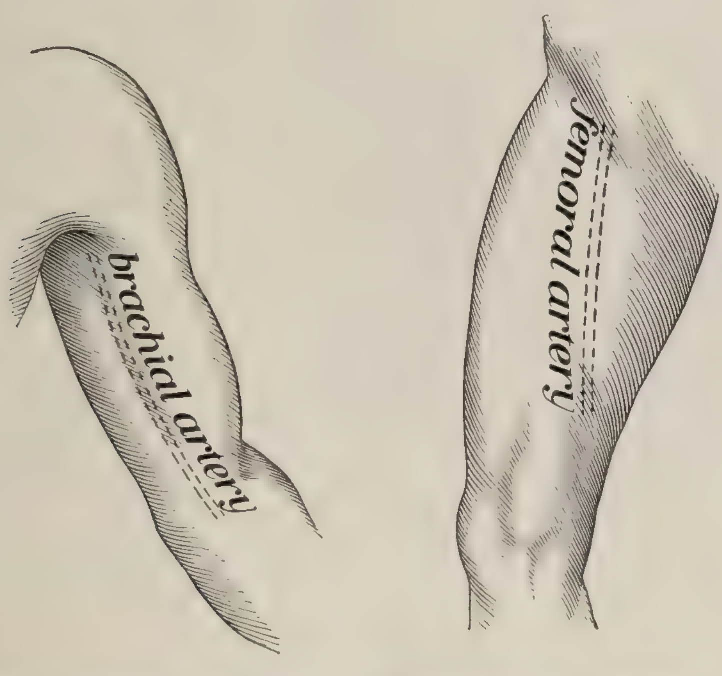

Fig. 68. — Regions where some large arteries lie near the skin.

2. Practice finding the pulse in the ankle or wrist, and then press on the artery *above* these points until the pulse is stopped.

Conclusion. — Where must a tourniquet be placed with reference to the cut and the heart (1) if a cut artery? (2) Vein?

Questions

1. Which are buried the deeper, — arteries or veins? Why?

Fig. 69. — Showing how to apply a tourniquet, made by tightly twisting a handkerchief so as to press a piece of wood against the brachial artery.

2. Which is more compressible, — a vein or an artery?

3. Should a person lean over a bowl when having nosebleed? Explain.

4. Why are those who take little exercise liable to have cold hands and feet?

5. What keeps the blood moving between heart-beats?

6. What are lacteals? Lymphatics?

7. Why does too severe exercise hurt the heart?

8. What effect have headache remedies on the heart?

9. What are colds?

Special Reports

1. The effect of tobacco on the heart.
2. How to treat a bruise. Explain the treatment.
3. How to restore from fainting.
4. The effect of alcohol on the heart.
5. The best way to stop the flow of blood from an artery. A vein.
6. How muscular exercise aids the heart.
7. How best to treat colds. Explain "Cold is the best prevention of cold."
8. The effect of work, pure air, and rest on the blood.
9. Changes in the composition of the blood as it courses through the body.

10. The systemic circulation. The portal circulation.
11. Lymph and its functions.
12. What is a tourniquet?

References

Hunter, *Essentials of Biology.* Chap. XXVI.
Hunter, *Elements of Biology.* Chap. XXX.

PROBLEM L

Some changes in the composition of the blood.

a. Absorption

Observations. — 1. What is ready to be added to the blood from the stomach? Small intestine?

2. What per cent of food that reaches the blood is absorbed by the villi of the small intestine?

3. What nutrient absorbed by the lacteals?

4. What is the portal system?

Conclusion. — Sum up all the changes in the composition of the blood, due to absorption.

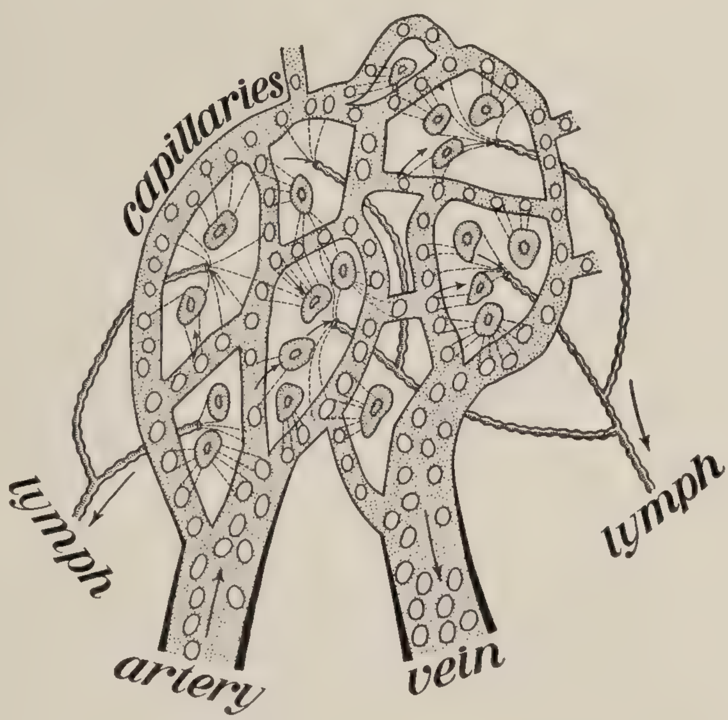

Fig. 70. — Diagram of the capillaries uniting an artery and a vein. The plasma is passing through the walls of the capillaries to nourish the body cells, after which some of it enters the mouths of the lymph vessels and the rest passes back to the capillaries.

b. A Special Use of Plasma

Observations. — 1. What part of the blood is able to pass through the walls of the capillaries? Note that it is now called *lymph.*

2. What is the reason for the process?

3. Study Figure 70. What does it show?

4. If the cells might be called "citizens," compare with the city of Venice.

Conclusion. — What are some of the changes that take place in the composition of the blood in the tissues?

c. The Liver

Observations. — 1. Refer to Figure 63 in Problem XLVII. What have you learned passes through the liver? Why?

2. What are the functions of the liver?

Conclusion. — What changes then take place in the composition of the blood in the liver?

Questions

1. Explain how the blood feeds the body.
2. What is the use of lymph vessels?
3. How is the food absorbed from the small intestine?
4. What is the portal circulation?
5. Where does the oxidation of nutrients take place?
6. What results when a candle or wood is oxidized?
7. What is the function of the lymph?
8. What is the function of the lymphatic vessels?
9. What vessel drains the lymph from the remainder of the body?

References

Hunter, *Essentials of Biology.* Chap. XXVI.
Hunter, *Elements of Biology.* Chap. XXX.
Davison, *The Human Body and Health* (Advanced). Chap. XI.
Eddy, *Textbook in General Physiology and Anatomy.*
Hutchison, *Applied Physiology.*

ADAPTATIONS FOR RESPIRATION AND EXCRETION

PROBLEM LI

A study of the organs and process of respiration.

a. Organs of Respiration in Frog

1. Living Specimen

Note. — Review Problem XXXVII, Section d.

2. Dissected Specimens or Chart, showing the Lungs in Place

Observations. — 1. Examine the dissected frog. Open the frog's mouth and find a slitlike opening (*glottis*) just back of the tongue. Insert a glass tube or blowpipe and force air down a short windpipe (*trachea*) which branches shortly into other short tubes (*bronchial tubes*) that lead to the lungs.

2. How much larger are the inflated lungs than the uninflated ones?

3. Are the walls of the lungs elastic? Do they look spongy? Can you see cell-like places? Are the lungs hollow?

Conclusions. — 1. Explain how the structure of the lungs affords a comparatively large area of moist membrane separating the blood on the one hand with its contained gases from the air on the other.

2. In what part of the lungs should you be likely to find the air poorest in oxygen?

3. Make a diagram of the respiratory system of a frog. Show just how it inhales oxygen and exhales carbon dioxide.

b. Mechanics of Respiration

1. Movements

Observations. — 1. Note the movements of your body while breathing, both when breathing quietly and when breathing deeply. Is there an elastic rebound as the breath goes *in* or *out ?*

2. Does the air leave the lungs without effort ?

Conclusion. — Which movement requires the greatest effort, taking in the air (*inspiration*) or sending it out (*expiration*) ?

2. The Diaphragm

Materials. — Small bell jar with opening at top for a 2-holed rubber stopper, sheet rubber tied over base of jar, with piece of chalk in the center of the rubber. Y-tube with toy balloons fastened to each branch of the Y and with the straight part passing through the stopper. When arranged as in Figure 71, the toy balloons will represent the lungs, or even air cells, the glass tube the trachea, the branches the bronchial tubes, and the glass jar the chest.

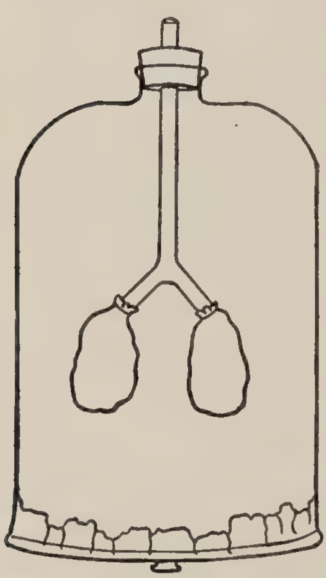

Fig. 71. — Diagram to represent action of the diaphragm.

Method. — Catch the knobbed place formed by the piece of chalk in the rubber sheet, and pull it downwards. Watch the effect on the toy balloons (lungs). Permit the membrane to return to place and observe again. Or set the apparatus on a bowl, the outer diameter of which is slightly smaller than the inner diameter of jar. This will cause the rubber to be pushed to an arched position. Lift the apparatus from the bowl, and the rubber flattens to a position taken on inspiration.

Observations. — 1. What is the effect on the size of the bal-

loons when the rubber (diaphragm) is pulled down? When relaxed?

2. What is the position of the rubber in each case?

Conclusions. — 1. Is there more or less room in the bell jar (chest) when the rubber (diaphragm) is pulled down?

2. Compare the effect of the rubber with the function of the diaphragm in your body. (See chart or Figures for the location of the diaphragm.)

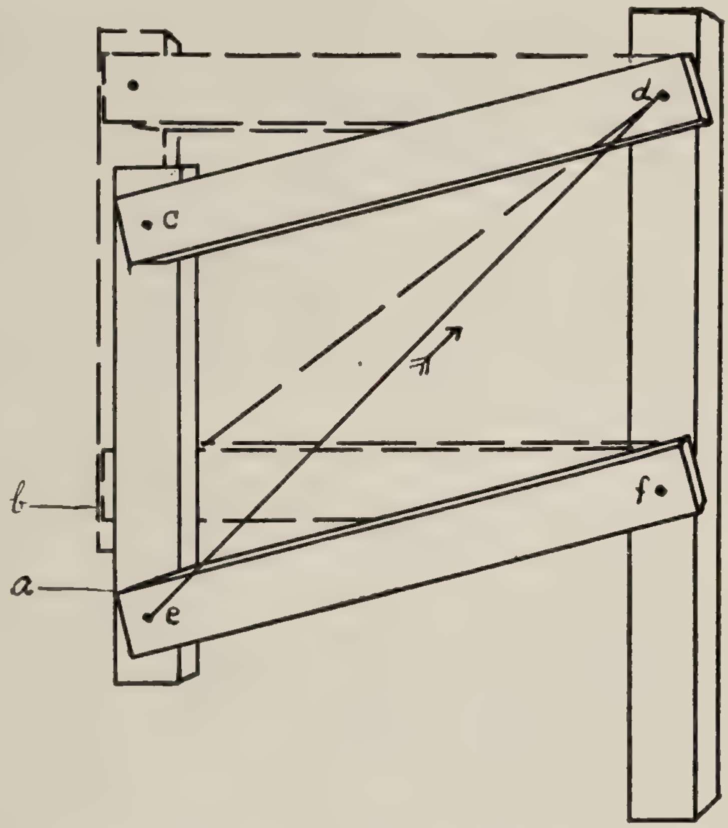

FIG. 72. — Diagram showing action of the ribs. *a*, position during expiration; *b*, position during inspiration.

3. The Ribs

Materials. — Make a model like Figure 72, using a strip of wood to represent the backbone, and other strips to represent the ribs and breastbone. Use small nails to form loose joints at the corners. Use a cord for the diagonal.

Method. — Hold the apparatus as in Figure 72 and pull the cord *ed* in the direction of the arrow. Note what happens.

Observations. — 1. What change in the distance between *ec* (breastbone) and *df* (backbone) when *de* is pulled? *Note.* — If *cd* and *ef* represent ribs, what does *ed* represent?

2. The ribs by their own elasticity bring the breastbone from the position *b* to the position *a*. Are the ribs fastened to the backbone with joints as in the apparatus?

Conclusions. — 1. What effect on the capacity of the chest when the muscles pull the ribs upwards and outwards?

2. What effect when the ribs by their own elasticity return to their original position?

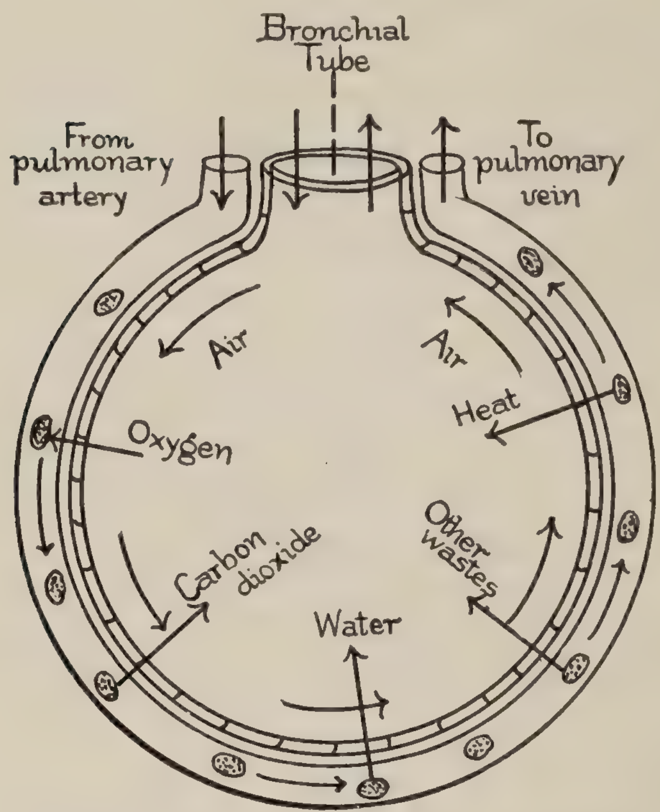

FIG. 73. — Diagram to show respiration in the lungs.

3. In what two ways do you now know the chest cavity may be enlarged?

4. How does air get into the air cells of the lungs?

c. Process of Respiration in the Lungs

Observations. — 1. How do air tubes end in the lungs?

2. Why are these endings so thin-walled?

3. What does Figure 73 illustrate?

Conclusions. — 1. Just how does the process of respiration take place in the lungs?

2. Just what changes take place here?

d. Cell Respiration

Observations. — 1. What does Figure 74 illustrate?

2. What wastes are formed when food is oxidized at the cells?

3. What desirable results when food is oxidized?

Note. — Observations 2 and 3 may be illustrated chemically as follows: —

Starch + oxygen = carbon dioxide + water + heat + muscular energy.[1]

$$C_6H_{10}O_5 + 6\ O_2 = 6\ CO_2 + 5\ H_2O + \text{heat} + \text{muscular energy.}$$

[1] Heat and muscular energy are both energy resulting from the oxidation of what? Where does the oxidation take place? About 30% is muscular energy, the remaining 70% is bodily heat.

Conclusions. — 1. What becomes of the oxygen taken in by the blood in the lungs?

2. What is the use of the oxygen?

3. What is the purpose of cell respiration?

4. What becomes of the wastes formed?

5. What becomes of the heat and energy formed?

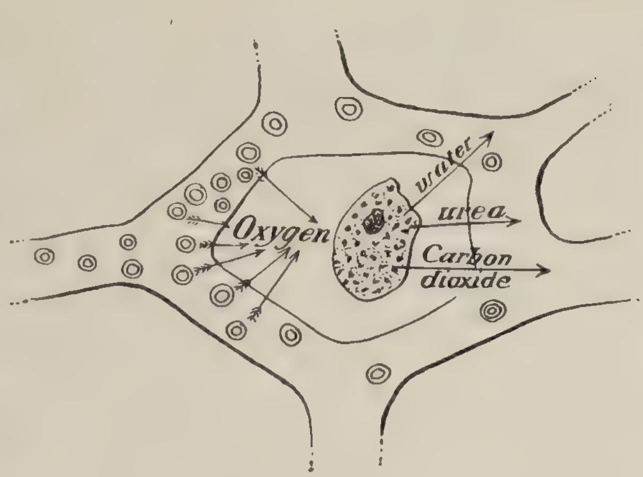

FIG. 74. — Diagram to show respiration of cells.

e. Capacity of Lungs (Optional)

FIG. 75. — Measuring the vital capacity of the lungs. The bottle was filled with water, which is being forced out by expiring the air from the lungs through the rubber tube slipped up into the mouth of the bottle kept under water in the pan. (Davison.)

Materials. — Gallon bottle, cork, rubber tubing, and a two-gallon vessel as a pan or water container.

Method. — Fill the bottle with water, invert in the two-gallon pan or container, remove the cork, insert the end of the rubber tubing, fill lungs to their fullest capacity, and force as much air as possible into the bottle.

Observations. — 1. What happens to the water as the air enters?

2. How much water flows from the bottle? What has taken its place?

Conclusions. — 1. How much air do you conclude came from your lungs?

2. If, say, 100 cu. in. remained in the lungs, what is the capacity of your lungs?

Questions

1. What lines the respiratory tract? Its function?
2. Of what use is oxygen in the body?
3. How do the air tubes end? Of what use are the air cells?
4. How may artificial breathing be produced?
5. Name some common diseases of the respiratory system.
6. What are adenoids? What results from them?
7. What are the signs of their presence?
8. How does tobacco affect the respiratory system?
9. How does alcohol affect the respiratory system?
10. How revive any one from drowning?
11. What does a cell gain from oxidizing food?
12. In what two ways is the chest enlarged?
13. Why are deep breathing exercises valuable?
14. Give some habits that impair the power of the lungs.

Special Topics

1. Consumption and its prevention.
2. Bronchitis and its prevention.
3. Pneumonia and its prevention.
4. The effect of tight lacing on the respiratory organs.
5. The movements of the ribs and diaphragm in breathing.
6. Cell respiration.

References

Hunter, *Essentials of Biology.* Chap. XXVII.
Hunter, *Elements of Biology.* Chap. XXXIII.

PROBLEM LII

A study of the products of respiration.

Materials. — Limewater, test tubes, piece of cold metal or cold windowpane, thermometer, small candle, splint.

a. General Tests

Method a. — Breathe on a cold piece of metal or glass. What takes place? Conclusion?

Method b. — Breathe on the bulb of a thermometer.

1. What are your observations? Conclusions?

Method c. — Breathe through a glass tube into a test tube half filled with limewater.

What takes place? Conclusion?

Method d. — Place a small lighted candle in a bottle, and after the flame has gone out, insert a flaming splint.

What takes place?

Observation. — Pour into the bottle two or three tablespoonfuls of limewater, and shake it.

What is the result?

Conclusions. — 1. What was formed by the burning candle?

2. Will this gas support combustion?

Review note. — Carbon dioxide is produced by the union of oxygen of the air with carbon which may be either in candles, wood, coal, or the fats and carbohydrates stored in your body or in foods.

3. What goes on in your body, as indicated by the last two tests?

Method e. — Hold a tin cup half filled with cold water over a small burning candle so as not to interfere with the flame and not so near as to heat the cup. What do you observe?

Conclusions. — 1. What is another of the results of oxidation of a candle?

2. What similar process goes on in your body?

3. Which is the more intense, — the heat of oxidation of the candle, or the heat of oxidation of the body? In which case is oxidation the more rapid? Which requires the greater supply of oxygen?

4. What is the purpose of a draft in a stove or furnace? How is the oxygen supplied for oxidation in the body? Where does the carbon come from?

b. Air in Room

Method. — Fill a large bottle with water, and take it into a room containing many people. Pour out the water. What is

now in the bottle? Test with a few tablespoonfuls of lime-water. What are your observations?

Conclusions. — 1. In what condition is the air in the room?

2. What is your conclusion concerning the ventilation?

c. Exercise and Respiration

Method. — Count the rates of breathing before and after rather vigorous exercise. What are your observations?

Conclusions. — 1. What effect on the temperature of your body? Heartbeat? Why so?

2. Where does the necessary energy for vigorous exercise or work come from?

3. Explain the effect of exercise upon the appetite?

d. Organic Waste

Method. — Breathe into a clean bottle, cork it, and set it aside in a warm place for a day or two. Now uncork the bottle and smell the air in it. What is the result?

Conclusions. — 1. What is your conclusion? *Note.* — An ill-smelling odor indicates the decay of organic matter.

2. Sum up your conclusions as to the wastes given off from the blood in the lungs.

Questions

1. Where does the energy of locomotion come from?
2. What are the objects of respiration?
3. Sum up all the products of respiration.
4. What are the changes of air in the lungs?
5. What are the changes in the composition of the blood in the lungs?
6. What is meant by oxidation? Results of oxidation?
7. Trace the course of oxygen until it reaches the cells.
8. What does a cell gain by oxidizing food?

Special Reports

1. The importance of fresh air for general health.
2. Comparison of the human body or any animal body with a steam engine.
3. The source of energy in animals.
4. The relation between muscular exercise and respiration.

References

Hunter, *Essentials of Biology.* Chap. XXVII.
Hunter, *Elements of Biology.* Chap. XXXIII.
Davison, *The Human Body and Health* (Advanced). Chap. XIII.

PROBLEM LIII

A study of ventilation.[1]

Materials. — A box of 7 × 10 inches base and 6 inches high placed on a side and having 4 half-inch holes bored in each end, and fitted with corks. Have a pane of glass to close the box. Place two candles in the box as shown in Figure 76.

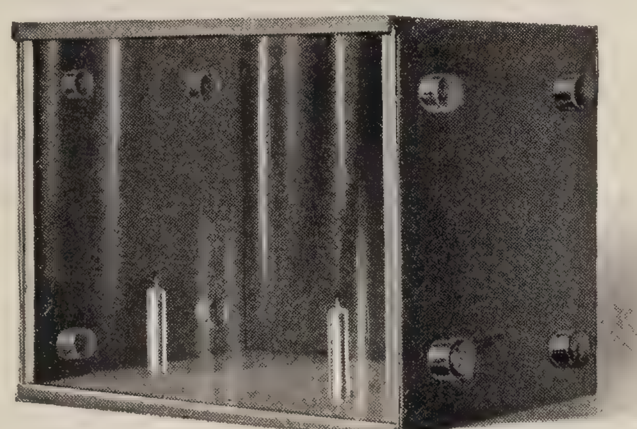

Fig. 76. — Showing arrangement of box with glass front, for experiment in ventilation. (After Davison.)

Method. — Light one of the candles so as to use up oxygen. The candle will also give off carbon dioxide, heat, and water. Remove the corks from one set of holes at a time, and observe the effects on the burning candle.

a. General Study

Observations. — 1. Place all the corks in. How long does the candle burn?

[1] Adapted from Davison.

2. Remove the two upper corks from one end. How long does the candle burn?

3. Remove the upper corks from both ends. Result?

4. Remove one upper and one lower cork from one end. Result?

Conclusions. — 1. Explain the result when all the corks are in place.

2. Explain the result when the upper corks in both ends are removed.

3. Explain the course of the air (oxygen) when the upper and lower corks at one end are removed. Which of the three trials is the most successful? Why?

4. Make cross-section sketches and explain the different trials as above. Use dotted lines and arrows to represent the course of the air. Draw a horizontal dotted line to represent the level of the candle tip (person's head). Label inlet *i* and outlet *o*.

b. Dust

Method. — Allow only a beam of light to enter the room on a sunny day. Shake various articles near this beam. Gather a pail of clean snow and melt it. Let a pan of water stand uncovered on the window sill or other outer exposure.

Observations. — 1. What is given off from the shaken articles?

2. Is the water from the melted snow clear and pure?

3. What do you notice on the surface of the water?

Conclusion. — What is your conclusion?

Questions

1. How can you show that plants give off oxygen?
2. Name some of the impurities of the air.
3. Why should people sleep with the windows open?
4. How should you ventilate a room heated with a stove?
5. Why should rugs be used in place of carpets?

6. Why is it healthful to have a pan of water on the radiator or stove?

7. What is a ventilator? Explain one.

8. How ventilate through the windows without causing a draft?

9. How is your schoolroom ventilated?

10. Why should a hat be well ventilated?

11. Explain the advantage of using damp sawdust or tea grounds when sweeping.

12. What months are worst for hay-fever patients? Explain.

13. What are the best ways for keeping dust out of the house?

14. Which becomes dusty sooner, an unpaved or a paved street? Explain.

15. Are there any special liquids to prevent dust in rooms? In roads?

16. Which is more cleanly, gas light or electric light? Explain.

17. In what ways does street sprinkling favor comfort and health?

18. What part of your city or town is dustiest? Least dusty? Why?

19. Explain the advantages of the vacuum cleaner.

20. Some of the advantages of traveling by boat?

21. What effect have autos and bicycles in stirring up dust? Preventive?

22. The effect of burning gas or lamps on the air in a room?

23. How can you tell when the air in a room is bad?

24. Name some ways of avoiding drafts in ventilation.

Special Reports

1. The need of ventilation.
2. Sweeping and dusting.
3. Hygienic habits of breathing.
4. Tenement houses and ventilation.
5. The black hole of Calcutta.

6. Ventilating systems.

7. Hay fever and its cure.

8. The comparative merits of plush and leather or leatherette for upholstering, so far as health is concerned.

9. The comparative merits of carpets and rugs.

10. The work of the street cleaning department.

11. What to do to prevent spread of fires in a building.

12. The public health laws of your state.

13. The work of the health department of your city or town.

14. Communicable diseases.

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Hunter, *Essentials of Biology*. Chap. XXVII.

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SUMMARY V

The nature and hygiene of some congestions or inflammations. (See Hunter, Essentials of Biology, page 394.)

a. Nature

Observations. — 1. Carefully note what is shown in Figure 77. What is the main difference shown between arterial capillaries (*arterioles*) in a normal state and when congested?

Note. — Whenever congestion or inflammation occurs, the

muscle fibers in the walls of the capillaries are either relaxed or injured, thus permitting more blood to pass through them.

2. Try naming some of the common characteristics of congestion or inflammation, — color, appearance, feeling, etc.

Conclusions. — 1. Just what do you understand is meant by the term 'congestion'?

2. What condition of the capillaries must be brought about in order to reduce congestions or inflammations?

b. Some Common Inflammations

Observations. — 1. What name is given to congestions in the nasal cavity? In the pharynx? In the larynx? In the chest? In the stomach? In the intestine?

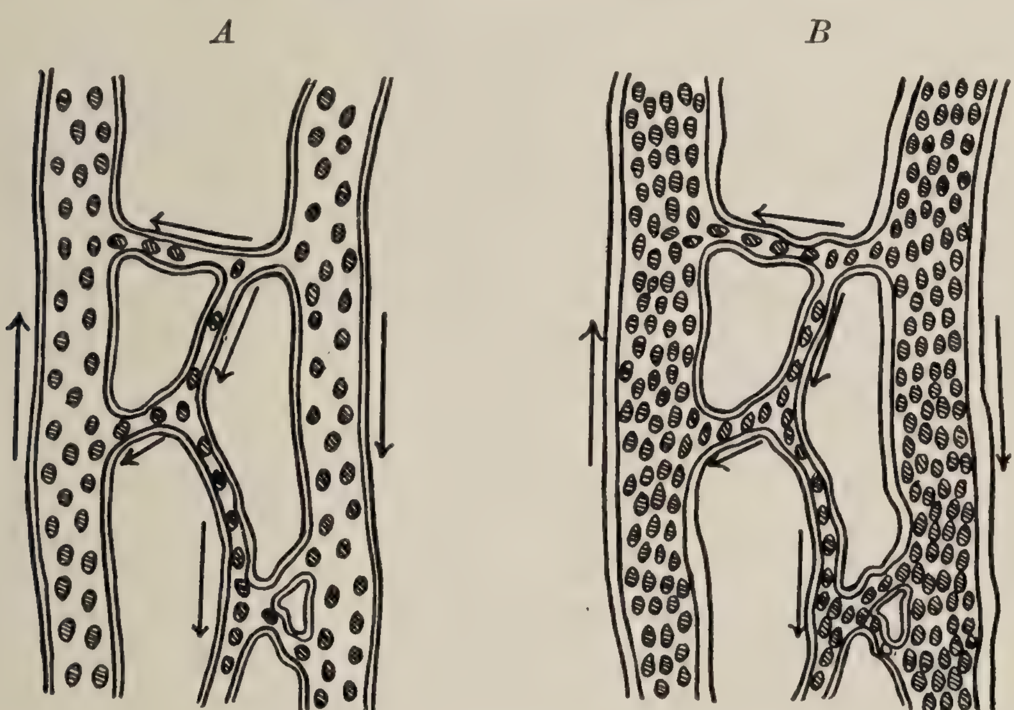

FIG. 77. — *A*, diagram of circulation from artery through capillaries to vein of frog. *B*, diagram of circulation in congestion, showing dilatation of blood vessels and crowding of corpuscles. (After Warren.)

2. What are some of the symptoms showing congestions in these organs?

Conclusions. — 1. What must be the general appearance and condition of these parts of the respiratory and alimentary tracts when so influenced?

2. Would such congested areas be more likely or less likely to be *susceptible* to the attacks of bacteria?

3. What, then, is the main danger connected with congestions? *Note.* — It is now understood that colds are infections, and that dampness and drafts are but favoring conditions for their development.

c. A Common Cause (Advanced Work)

Observation. — What are some of the symptoms of common "colds"? *Note.* — Colds start as *active congestions*, thus widening the arterioles with a consequent more rapid flow of blood, finally resulting in a more passive state, with white corpuscles thickly adhering to the internal walls of the capillaries.

Conclusions. — 1. How must myriads of clinging white corpuscles affect the size of the bore of capillary tubes?

2. Show how these tubes now become gorged with blood.

d. Summary of Hygienic Hints[1]

Avoid arterial dilation in inflamed areas: —

a. In diarrheal conditions by,
  1. Avoiding heavy meals. Why? What effect on congestion?
  2. Light diet. Something easily digested and absorbed.

b. In colds by,
  1. Avoiding chilling the skin. Why? *Note.* — Heat increases the size of the capillaries of the skin, while cold decreases it. What would become of the blood in the capillaries of the skin if it was driven out by *sudden* cooling?
  2. Keeping warmly clad. Why?
  3. Keeping sleeping rooms well ventilated but not *too cold.*
  4. Discontinuing cold baths temporarily, if such had been the habit. Why?
  5. Avoiding all dampness. Why?
  6. Keeping *the full share of the blood in the skin.* What might be the effect if even the feet were permitted to become chilled?
  7. Breathing *fresh air*, but not at the expense of *chilling* the skin.

[1] Adapted from Hough and Sedgewick, *The Human Mechanism.*

8. Hot baths, hot lemonade, or other hot drinks when the cold is just starting. Why? *Note.* — These avail little after the disease is well started. It then becomes a struggle between the body and the disease.
9. In general, avoiding all drugs, except as prescribed by a physician.
10. Moderately exercising the muscles, because of the following normal physiological effects:
    (*a*) Temporary relief of congestion. Why?
    (*b*) Better regulation of body temperature. Why?
    (*c*) Greater physical and chemical changes in the body and lymph.
    (*d*) Freshening the lymph flow to the cells.
    (*e*) Keeping up the regular work of the heart.
    (*f*) Keeping up the depth and frequency of the respiratory movements, and therefore better ventilation of the lungs.
    (*g*) Increasing the activity of the digestive organs and glands.

PROBLEM LIV, PART I (Experimental)

To study some of the functions of the skin of man.

Materials. — Compound microscope, hand lens, ether or alcohol, large glass jar, and two thermometers.

a. Experimental

Method a. — Touch the skin at several places with the point of your pencil.

Observations. — 1. Do you find any place insensible to the touch?

2. Are all parts equally sensitive?

Conclusion. — What is one function of the skin?

Method b. — Cool a large glass jar. Insert one hand in it, and close the rest of the opening by wrapping the wrist with a handkerchief or towel. Watch the inner surface of the jar for a few minutes.

Observation. — Does anything collect on the inner surface of the jar?

Method c. — Weigh yourself just before taking exercise in the gymnasium. Weigh yourself at the end of the period.

Observation. — What is the loss in weight? Why is there a loss, if any?

Conclusion. — What is another function of the skin?

Method d. — Wrap the bulb of a thermometer with a strip of cloth, and wet it with water of the same temperature as the room. Let it stand a short time near a thermometer with a dry bulb.

Observation. — Read the two thermometers. Do they agree? What difference do you note? *Note.* — As water or any other liquid evaporates, it uses heat, which is taken from near-by substances.

Conclusion. — What caused the wet thermometer to read differently from the dry one?

Method e. — Place a few drops of ether or alcohol on the back of the hand and note results.

Observations. — 1. What happens to the liquid?

2. What is the effect on the hand? (What sensation?)

Conclusions. — 1. What do you conclude regarding the effect of evaporation on temperature?

2. Where did the moisture come from that collected on the inside of the bell jar? What is it called?

3. What is given off at all times by the skin?

4. What is its function?

Method f. — Examine the palm of the hand or the inside of the fingers where they are ridged with a hand lens, and see if you can find very small pits (*sweat* or *perspiration pores*) on the ridges.

Observation. — Where are the pores located? Are there few or many?

b. Structure (Optional)

Method g. — Study a prepared slide, showing cross section of the skin. Use low power objective, or study any good Figure.

Observations. — 1. Find two layers of the skin, an outer (*epidermis*) and an inner (*dermis*).

2. Do you find any elevations of the dermis that extend into the epidermis? Describe one.

3. Note some coiled tubes (sweat glands) which lead to the surface of the skin. Do they seem to correspond in location with the openings seen with the hand lens? *Note.* — The instructor may well here call attention to the hairs and oil glands.

Conclusions. — 1. Where is the perspiration formed (*secreted*)?

2. What is one of its functions?

3. Is the skin a sense organ? Explain.

4. Write a summary of the main functions of the skin.

5. Tell something of the structure of the skin.

Questions

1. Why should much water be drunk daily?
2. When do you perspire the most?
3. Why should the skin be kept clean?
4. What is the chief physiological use of clothing?
5. Why is it necessary to bathe frequently?
6. How does a corn differ from a blister?
7. What effect have rubber shoes on the feet?
8. How should you treat burns?
9. State facts that show the skin gives off wastes.
10. Explain the function of perspiration.
11. Why is heat more oppressive in moist weather?
12. What is the temperature of the healthy body?
13. What may cause baldness?
14. What is the cause and what the cure for dandruff?
15. What is the relation of bodily heat to work performed?
16. How treat cuts?
17. Why should most people take a moderately cold bath daily?
18. What is the effect of alcohol on the bodily heat?
19. What is the use of a hot bath? Cold bath?
20. What care should be observed when swimming?
21. Why is ammonia used in refrigerators or in cooling?
22. Why never employ a doctor advertising to cure cancer?

Special Reports

1. The function of the kidneys.
2. The functions of the skin.
3. The care of the hair and nails.
4. Advantages of hot and cold baths.
5. Cause and cure of dandruff.
6. Influence of alcohol on the skin.
7. The relative values of cotton and wool for clothing.
8. Artificial ice.
9. The bodily excretions.

References

Hunter, *Essentials of Biology.* Chap. XXVII.
Hunter, *Elements of Biology.* Chap. XXXIV.
Davison, *The Human Body and Health* (Advanced). Chap. XVI.
Eddy, *Textbook in General Physiology and Anatomy.*
Martin, *Human Body.* Chap. XVIII.

PROBLEM LIV, PART II (Summary)

A final study of the changes in the composition of the blood as it passes through various organs of the body.

a. Normal Changes

Observations. — 1. Fill in the following tabulation: —

Income of Blood from	Organs	Outgo of Blood to
	1. Alimentary Canal ($\frac{9}{10}$ from small intestine)	
	2. Tissues (muscle, nerve, bone, etc., all living cells) . .	
	3. Liver	
	4. Lungs	
	5. Kidneys	
	6. Skin	

2. What should be the relationship between the income and outgo columns? Try to prove it.

Conclusions. — 1. Write a paragraph summing up all the normal changes that take place in the composition of the blood.

2. What different bodily functions are involved in these changes?

b. A Special Change

Observations. — 1. Study Figure 78. What is one function of the white corpuscles?

2. What happens concerning these corpuscles in case of cuts, bruises, or splinters?

Conclusions. — 1. Why are the white corpuscles often called a kind of "Jack of all trades"?

2. Write an additional note on possible changes in the composition of the blood, due to disease or accident.

Fig. 78. — Diagram of a capillary network, showing the white corpuscles creeping through the walls of the capillaries to eat bacteria, causing a boil at *m*.

Questions

1. Which of the organs listed in the table above are purely excretory organs? Which partly so?

2. What are excretions?

3. What are the functions of the liver?

4. What is the cause of boils?

5. Give the cause of the changes that take place in the composition of the blood in the muscles.

6. How does the life of one of the body cells remind one of the life of a small animal in a pond?

Special Reports

1. The bodily excretions.
2. Causes of changes in the composition of blood.
3. The cause of boils.
4. Changes in the composition of the blood.

References

Hunter, *Essentials of Biology*. Chap. XXVII.
Hunter, *Elements of Biology*. Chap. XXXIV.
Davison, *The Human Body and Health* (Advanced). Chap. XVI.

SUMMARY VI[1]

A final comparison of human body cells with a community, — physiological division of labor.

a. Division of Labor

Observations. — 1. Note the different varieties of cells shown in Figure 46, from various parts of the body. Why may they be called "tiny citizens of the body community"?

2. Name some cells that belong to the body community that are not shown in the Figure.

Conclusions. — 1. Show how the *red blood corpuscles* of the body may be compared to railroad men. *Note.* — Why canals instead of railroads in the body community?

2. How may the *digestive cells* be compared with farmers? *Note.* — Keep in mind the work of the farmer in converting crude soil into things suitable for man's consumption.

3. How may you compare the *colorless* or *white blood corpuscles* with soldiers and policemen?

4. Show how *nerve cells* may be compared with governors and teachers.

5. Compare cells in the *skin* and *kidneys* with *scavengers.*

6. What may the *muscle cells* be compared to in a human community?

[1] The field work for Problem LVI, II, Sanitary Map, and Sanitation should now be started.

7. Compare the *ciliated cells* of the windpipe with efficient housemaids.

Observation. — Review your definitions of tissues and organs.

Conclusions. — 1. Show how tissues and organs may be compared with companies and regiments of men.

2. Show how division of labor is illustrated in the human body.

b. Special Questions

1. What advantage in each cell doing only a special piece of work instead of doing everything an animal needs to do, as in the amœba?

2. How does the efficiency of wild tribes of men compare with civilized men? What is the main difference?

3. What do we mean when we say "higher animals"? Just in what sense are they "higher"?

4. Should men and women be educated to do the same work?

5. What is meant by the term "progress by specialization"?

6. Show how *equal work*, as between men and women, is a violation of nature's law of progress, and would cause race degeneration.

7. What are tissues? Organs?

8. Name some tissues in the human body. Why may they be called "master tissues"?

9. Define the following terms: "anatomy," "physiology," "hygiene," "biology."

NERVES AND THEIR CONTROL

PROBLEM LV

A study of the nervous system, reactions to stimuli, and habit formation.

a. Anatomy

Materials. — Frogs preserved in alcohol or formalin, scissors, forceps, hand lens, charts showing nervous system of man. (Optionally use prepared specimens of the nervous system of frogs or of mammals.)

Note. — The nervous system of man and animals is *primarily* a device for making locomotion safe.

Observations. — 1. Open the abdomen of a frog and remove the organs found in it. Find some white cords (*nerves*) near the back.

2. Trace some nerves into the legs, dissecting away the muscle.

3. Carefully remove the upper half of skull, and find some white lobes (*brain*).

4. Cut away the skin, muscles, and upper half of the backbone, so as to trace a large nerve in it (*spinal cord*).

5. Refer to a chart showing nervous system of a frog, and notice the branching.

Conclusion. — Compare the nerve cords with a telegraph system. What corresponds to headquarters? (Study the function of the brain in any good text.)

Observations. — 1. Note the white elongated hemispheres of the forebrain, or *cerebrum.* The two anterior projections of the cerebrum are called *olfactory lobes.* Where do these lobes seem to lead? What is the meaning of the term 'olfactory'?

2. Just back of the cerebrum find the *mid-brain.* The dorsal part is enlarged into two large lobes, known as *optic lobes.* Are there branches leading from them? Where do they lead? *Note.* — The term 'optic' refers to sight.

3. How do the optic lobes compare in size with the cerebrum?

4. The hindmost part of the brain is known as the *medulla.* To what does it join posteriorly?

Conclusion. — Write a paragraph telling what you can of the nervous system of the frog.

Observation. — Study Figure 79. The cell much branched is known as a *neuron,* or a unit of the nervous system. The brain and spinal cord contain many millions of them.

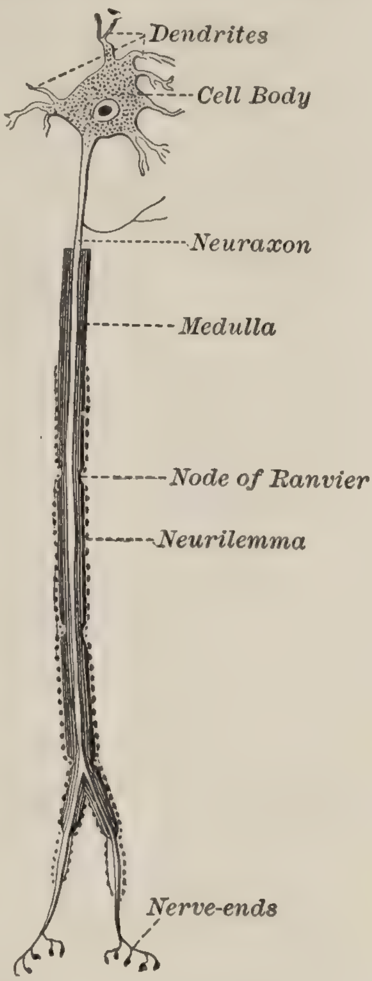

FIG. 79. — Diagram of a neuron or nerve unit.

Conclusions. — 1. If a branch from one should end in a muscle, in which direction would messages travel through it?

2. If a branch from a neuron should end in the sensitive part of the tongue or tip of the finger, in what direction would messages travel through it?

b. Reactions

1. Reflex

Observations. *Note.* — Reflex action is involuntary action taking place before the brain has had time to aid or interfere in any way.

1. Feign a blow at a person's face. Result?

2. Tickle the inside of the nose with a feather. Result?

Conclusion. — What do you judge is the especial reason for each of the reflex actions just noted?

2. Voluntary Reaction

Observations. — 1. Send any whispered word around the class. Take the time at instant of starting the word, by the instructor, and also again when received, to determine time of transmission. Divide time of transmission by number in the class. What is the average time of voluntary reaction?

2. Let members of class stand and touch hands. The instructor will now send a touch signal, as a long and short pressure of fingers, to imitate a telegraph signal. Get the average reaction time as before. How does it compare with the first or ear reaction?

Conclusions. — 1. How do voluntary reactions differ from involuntary ones?

2. How do ear reactions compare with touch reactions?

c. Frog

Observation. — 1. Refer back to your study of the frog. What reactions have you noticed? Try to classify them into voluntary and involuntary.

Conclusions. — 1. Tell how the reactions of the frog compare with those of man; that is, which do you think has the better nervous system?

2. Show how the note at the beginning of the problem may apply to any animal.

d. Sources of Knowledge and Action

Note. — "The mind is a collective term for the operations of the nervous system."

Observations. — 1. Touch the back of the hand with a pencil point.

2. Close the eyes and place on different parts of the tongue several substances, as sugar, vinegar, salt, weak ammonia, etc. What part of the tongue is most sensitive to each?

3. Test your hearing by determining how far off the tick of a watch can be heard.

4. Determine the farthest distance you can identify any certain letter in a book. Also nearest distance.

Conclusions. — 1. Write a paragraph telling all you can concerning your lead pencil. Just *how* have you obtained your information?

2. Are you able to rely on your impressions; that is, do they vary from day to day? *Note.* — "The work of science is to find out in some degree the real nature of the universe." Your knowledge of science must come through *your own* senses. The ultimate end of science is the regulating of human conduct. "*Seeing true means thinking right. Right thinking means right action.*" Wrong thinking brings wrong action, which causes misery, which is nature's protest against this wrong action.

3. Touch your finger to a hot stove. Show just how the result explains the above note.

4. Explain the statement, "There is no alleviation for the woes of life except *absolute veracity of action*, the resolute facing of the world *as it is*."

5. Explain the statement, "As food must be formed into tissue, so must perception pass over into action"; that is, are sensations for any other purpose than proper action?

e. Habits

1. Beneficial

Observations. — 1. Recall your experience in learning to write. Compare with your ability to do so at present. What has happened?

2. Try doing a difficult gymnastic feat. As nerve cell after nerve cell (neuron after neuron, see Figure 79) sends out orders to the muscles, do they seem to be able to handle the situation in improved ways? Explain.

3. Do you suppose the neurons of a child just learning to walk find it easy to send out just the right orders to the muscles? Explain your answer.

4. Do you now find it so easy to walk that you can also think of distant or other things at the same time? If so, of what advantage is it to you?

5. When watching a group of people learning to do anything in concert, as drills of children, etc., or of soldiers, how did the first rehearsal compare with the last? *Note.* — As soldier after soldier, or child after child, became better able to do his part, so neuron after neuron of the brain and spinal cord became better able to do their parts, until finally there is habitual action.

6. Explain the following story: "A practical joker saw a discharged veteran carrying his dinner home; he suddenly called out, 'Attention'; whereupon the veteran instantly brought his hands down, dropping his dinner in the gutter."

Conclusions. — 1. How are habits formed? Illustrate your answer, using the term "nerve cell."

2. Mention one advantage of a good habit, as walking, etc.

Observations. — 1. Suppose a man must concentrate his mind on just how to walk, or to digest, or to dodge an unexpected blow, or to resist falling, etc. How would it affect the *safety* of his life?

2. Mention as many actions of your body as you can that tend to *safety and comfort of life*. Are the habits of *contentment* and *self-control* of any value?

Conclusions. — 1. Write a paragraph on the increased effectiveness and power acquired through good habits.

2. Is it easy to break a habit? Explain your answer.

3. Explain the statement, "Life is but a tissue of habits."

2. Harmful

Observations. — 1. Boil a pipeful of tobacco in a pint of water, Put the resulting solution into a small aquarium containing a tadpole or a small goldfish. Results?

2. Draw the smoke from 5 or 6 cigarettes through water in the bottle as shown in Figure 80. Pour the liquid into a small aquarium containing a tadpole or goldfish. Results?

Conclusion. — What is the result of tobacco poison on the nervous system?

Observations. — 1. Why do life insurance companies consider even "moderate drinkers" as an "extra risk"?

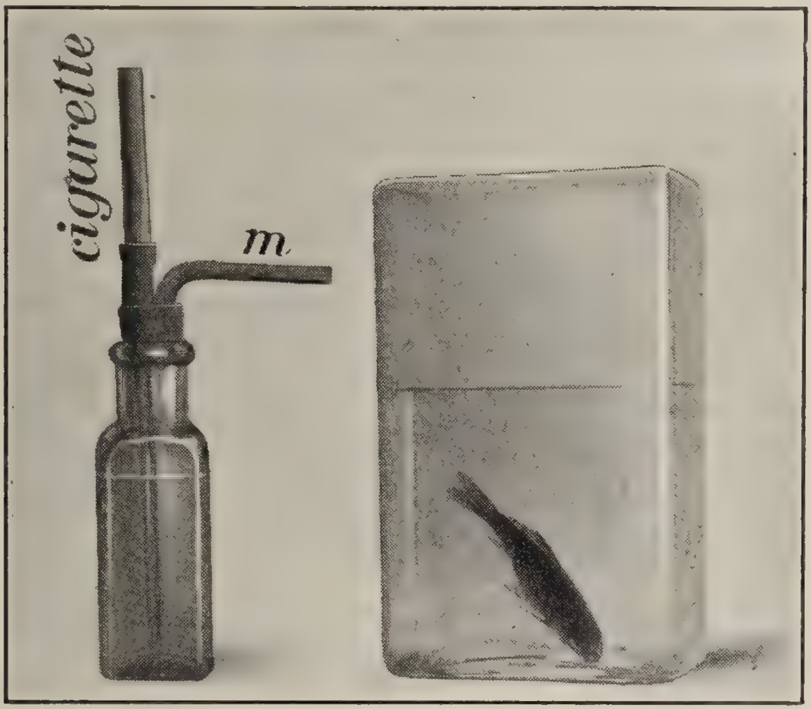

FIG. 80. — Experiment to show how tobacco affects the nerves. *m* is a tube through which the air is sucked from the bottle nearly full of water. This draws smoke from the lighted cigarette through the tube down into the water. The poison in the smoke from six cigarettes was thus drawn into the water which was later poured into the jar with the fish, putting it to sleep in one half hour, and finally killing it.

2. What is the recognized effect of opium on the sense organs?

Conclusions. — 1. What do you think of the *reliability* of impressions from the sense organs when they are affected by alcohol, opium, or tobacco?

2. Explain the statement, "Every failure in the sense organs, every form of deterioration of the nerves, shows itself in reduction of power."

Observations. — 1. Study the following statement: "The hell to be endured hereafter, of which theology tells, is no worse than the hell we make for ourselves in this world by habitually fashioning our characters in the wrong way. *Could the young*

but realize how soon they will become mere bundles of habits, they would give more heed to their conduct while in the plastic state. We are spinning our own fates, good or evil, and never to be undone. Every smallest stroke of virtue or of vice leaves its never-so-little scar. The drunken Rip Van Winkle, in Jefferson's play, excuses himself for every fresh dereliction by saying, 'I won't count this time.' Well! he may not count it; but it is being counted none the less. *Down among his nerve cells and fibers the molecules are counting it, registering and storing it up to be used against him when the next temptation comes. Nothing we ever do is, in strict scientific literalness, wiped out.* Of course this has its good side as well as its bad one. As we become permanent drunkards by so many separate drinks, so we become saints in the moral, and authorities in the practical and scientific spheres, by so many separate acts and hours of work. *Let no youth have any anxiety about the upshot of his education whatever the line of it may be. If he keeps faithfully busy each hour of the working day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning, to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out."* — JAMES, *Psychology.* Are habits formed suddenly? Are we always conscious that habits are being formed?

2. Man is a bundle of appetites. What relation should his appetites bear to his better judgment?

Conclusions. — 1. Show that it is foolhardy to permit of any lack of perfect self-control.

2. Explain the statement, "There seems no possibility of improving our race except as the young are led to see the manliness and dignity of self-control."

Questions

1. Explain the statement, "One by one the little records within the brain cells (neurons) build up our lives and our characters, and determine our habits of action and of thought."

2. Why do employers favor boys who do not use tobacco?

3. Why will not railroads employ even "moderate drinkers"?

4. Why is an idler in the third grade likely to be an idler in the sixth?

5. Why is a high school drone quite likely not to become a capable college student?

6. Explain the statement, "Sow an act and reap a habit; sow a habit and reap a character."

7. Why is it important that correct habits be formed early in life?

8. Explain the following: "The chains of habit are generally too small to be felt till they are too strong to be broken."

Special Reports

1. Necessity of food, fresh air, and rest.
2. Necessity of good or right habits.
3. The waste of bad habits.
4. Self-control *vs.* appetite.
5. The habit of using headache powders and patent medicines.
6. The value of *regular* habits of work, exercise, and rest.

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PERSONAL AND CIVIC HYGIENE

PROBLEM LVI

A study of personal and civic hygiene.

Note. — Disease germs are bacteria, or sometimes protozoa, that develop in the body and set free poisons. Nearly all that attack us come from the bodies of sick people. Therefore, we should endeavor to destroy all that come from such sources.

I. HOW BACTERIA MAY ENTER THE BODY

Materials. — A dozen sterilized Petri dishes, containing nutrient gelatin.

Observations. — 1. See that they have been kept well covered. Label them 1 to 12. Set aside No. 1, labeled "not exposed," then in a temperature of about 70° F. Examine it for results after a day, two days, three days.

2. Sweep a corner of the room, thus stirring up a little dust. Open dish No. 2 and expose it to the air for half a minute. Set it aside and observe it daily.

3. Touch the gelatin of No. 3 with the tip of a lead pencil which has previously been moistened in the mouth. Set it aside and observe it daily.

4. Touch the gelatin of No. 4 with the tips of the fingers, that have not been recently washed in soap and water. Set it aside and observe it daily.

5. Moisten the gelatin of No. 5 with water. Set it aside and observe it daily.

6. Moisten the gelatin of No. 6 with milk. Set it aside and observe it daily.

7. Touch the rim of a public drinking cup to the gelatin of No. 7. Set it aside and observe it daily.

8. Cause a house fly to walk across the gelatin of No. 8. See that the legs of the fly touch the gelatin at several places. Set it aside and observe it daily.

9. Touch the gelatin of No. 9 with dust from the street or roadway. Set it aside and observe it daily.

10. *Note.* — Reserve the rest for second trials, if necessary. The above cultures are known as *inoculations,* as they were inoculated; that is, germs were planted in a favorable growing place.

11. Tabulate your results as follows:—

	1 Not Exposed	2 Air of Room	3 Pencil	4 Finger Tips	5 Water	6 Milk	7 Cup	8 Fly	9 Dust of Street
Date of appearance of colonies . . .									
First appearance of colonies, number, size, color, etc. .									
Changes in size, color, etc., at the end of the trial									

Note. — Each spot on the gelatin represents a colony of bacteria, or mold, which has developed from germs originally placed there.

Conclusions. — 1. From what different sources may bacteria enter the body?

2. Explain just *how* bacteria may enter the body from the different sources enumerated in your last answer. *Note.* — It has been recently proved that cracked earthenware dishes,

or pottery, may harbor germs in the cracks in such numbers as to be a dangerous means of introducing them into our bodies.

3. Note that such diseases as smallpox, scarlet fever, and consumption may be taken by breathing the germs of these diseases in with air, and so are called *contagious* diseases. The healthy thus acquire the diseases by coming near the sick or

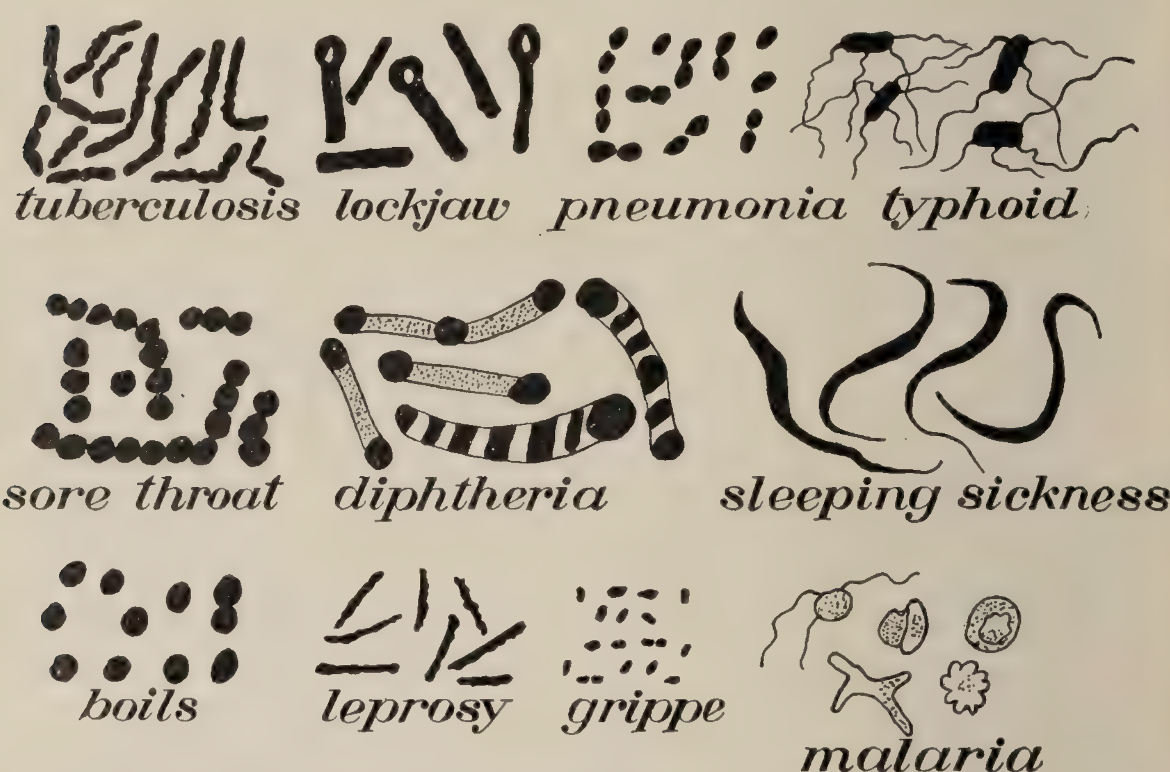

FIG. 81.—Germs that cause various diseases. Highly magnified. (After Davison.)

where they have been. Malaria and such diseases are *non-contagious,* as they require the bite of an insect or at least the breaking of the skin in order to introduce the disease. They are also *infectious,* as they are caused by tiny *parasites* which feed on the human body as a *host.* Such diseases as diabetes and insanity are *noninfectious* as they are not caused by parasites.

4. What disease germs may enter the body from drinking water or milk?

5. What might happen if the excreta from a typhoid patient was thrown out near the sources of streams that supply villages lower down with water?

6. Explain how such excreta may be disinfected.

7. Suppose a person with tuberculosis spits in public places. What is quite certain to be the result?

8. Explain why it is criminally careless for any one to spit in public places, on walks, etc. *Note.* — Pocket waterproof sputum cups are now manufactured and should be used by all consumptives. They may then be burned or disinfected by carbolic acid or lysol. Under no circumstances should the sputum be allowed to dry up. Why?

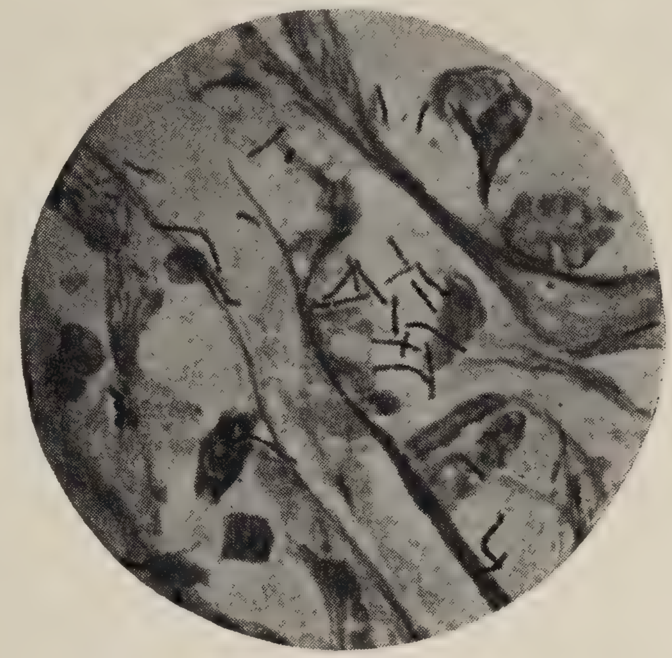

FIG. 82. — Germs of tuberculosis from the spit of a consumptive.

9. How do you suppose all the disease germs that are in dust originally got there, such as of consumption, pneumonia, catarrh, meningitis, measles, influenza, and scarlet fever? Is there much spitting in your town or city? Where, if any?

10. Since dust about human habitations must inevitably contain germs under present conditions, what are some of the best means of keeping them out of our bodies? *Note.* — The dust in public buildings may be kept down by using sawdust dampened with water, to which has been added $\frac{1}{2}$ pint of kerosene and a tablespoonful of formalin. Why add formalin?

11. Why should feather dusters not be used in dusting? *Note.* — A cloth dampened with water containing a little kerosene makes a most excellent duster. Why use kerosene?

12. Why may carpets be detrimental to health?

13. How may the leaves and covers of a book become carriers of the germs of some diseases? Why should all publicly used books be at least covered?

14. May germs enter the body through breaks in the skin? What causes the soreness of any ordinary cut?

II. A SANITARY MAP, AND SANITATION

Note. — This work should be started as field work several weeks before it is taken up in the class room.

Observations. — 1. Get a map of the neighborhood, village, borough, or township. If none can be obtained, sketch one as best you can. Mark with a star any houses where any transmissible diseases have been, or are at present. Indicate the number of cases with a figure. Also indicate the nature of the disease with an initial as, *2T would mean, two typhoid cases at this place. Get your information through neighborhood inquiry, or from quarantine placards, otherwise through public officers, such as health officials, either local or state. Which sort of disease is most common?

2. Mark on the map the location of any cesspools, or sewage emptying into streams.

3. Locate any marshes or stagnant ponds. Also any open rain barrels, or tin cans, etc., which may hold rain water. Do any of them contain any wigglers or mosquito larvæ?

4. Locate any garbage dumps. Also any garbage pails that are commonly left open. Are there any places where the garbage is left in the back yard? Are children permitted to play about such places?

5. Locate any manure heaps near stables. Also any unclean stables, either for horses or cows. If there are any manure heaps, find out whether any measures are taken to kill maggots, or the young of flies. What, if any?

6. Locate any public restaurants where there is an excessive number of flies about, and permitted on the food and in the building. Are such places cleanly?

7. Locate any dry closets or outhouses. Also piles of decaying vegetable matter. Also any places where the soil is commonly polluted by the excreta of human beings being permitted to remain on the surface for any length of time. *Note.* — It is said that barefoot children running about on the polluted soil of some of the regions of our Southern states, as

well as Porto Rico and the Philippines, contract a certain disease. What?

8. Locate any public places where there is much spitting on the floors or walks. Is the place uncleanly in other respects? Are there flies about?

9. Locate any stores exposing any foods — especially fruits and vegetables — for sale, so that dust and flies may readily come in contact with them. Are these foods also handled by those who are marketing?

10. Locate any public fountains with drinking cups.

11. Locate any railroads. *Note.* — Any railroads using the ordinary means of disposing of excreta become like open sewers or worse. Why? All such excreta should be collected in retaining vessels and disposed of at various stations along the route.

12. Locate any excessively dusty streets. Also any that are unduly shady or continually damp.

Note. — The work of the above tabulation may be most profitably done by dividing it among different members of classes, — especially if the district studied is very large, or populous.

Conclusions. — 1. Does there seem to be any connection between the sanitary condition of the district and the number and kind of diseases found?

2. Can you suggest any improvements and give your reasons for them?

3. Try to plot a curve showing variations in the death rate due to any of the diseases you have located on the map. Get the data for twelve months from the local or state health department. Try to sum up all the different factors concerned and see if you can account for any variations shown during the year.

(See next section for instructions for plotting curves.)

III. INFANT MORTALITY CURVE

Method a. — Let the alternate vertical lines of a sheet of cross-section paper represent the months of the year in order,

At the top of the left vertical line but one write Jan.; the fourth, Feb., etc., or rule paper as in Figure 83.

Let the spaces between the heavy horizontal lines represent 50 deaths.

Refer to mortality tables published by Departments of Health of various cities and get such data as is represented in the following table,[1] which was taken from one published in the Annual Report of Department of Health of the city of New York, 1908, p. 841 (except data for flies, which came from a supplemental report of the Merchants' Association of New York).

Date	Jan. 4	Feb. 1	March 7	April 8	May 9	May 23	June 20
Diarrheals under five	32	26	36	51	62	49	86
Under one year . .	262	254	279	275	284	268	268
Mean temp. (Fah.) .	38.2	28.9	32.2	49.2	53.8	66.4	72.6
Average . . . . Prevalence of flies .	0	0	0	0	0	0	250

Date	July 4	July 25	Aug. 8	Sept. 5	Oct. 3	Nov. 7	Dec. 5
Diarrheals under five	202	424	327	244	192	72	39
Under one year . .	354	508	469	382	311	217	208
Mean temp. (Fah.) .	79.5	80.6	81	69.4	61.1	44.6	43.1
Average . . . . Prevalence of flies .	2000	1900	2200	200	400	0	0

[1] Courtesy of Dr. W. H. Allen, Director of the Bureau of Municipal Research, New York.

Now since there were 32 deaths the week of Jan. 4, we take such a part of the January column measured toward the right on line OX as 4 days is a part of 31 days and make a tiny cross, and measure up on the line OY $\frac{32}{50}$ of the height of the first square and make another tiny cross. The first tiny cross locates a vertical line, or imaginary line, while the second cross

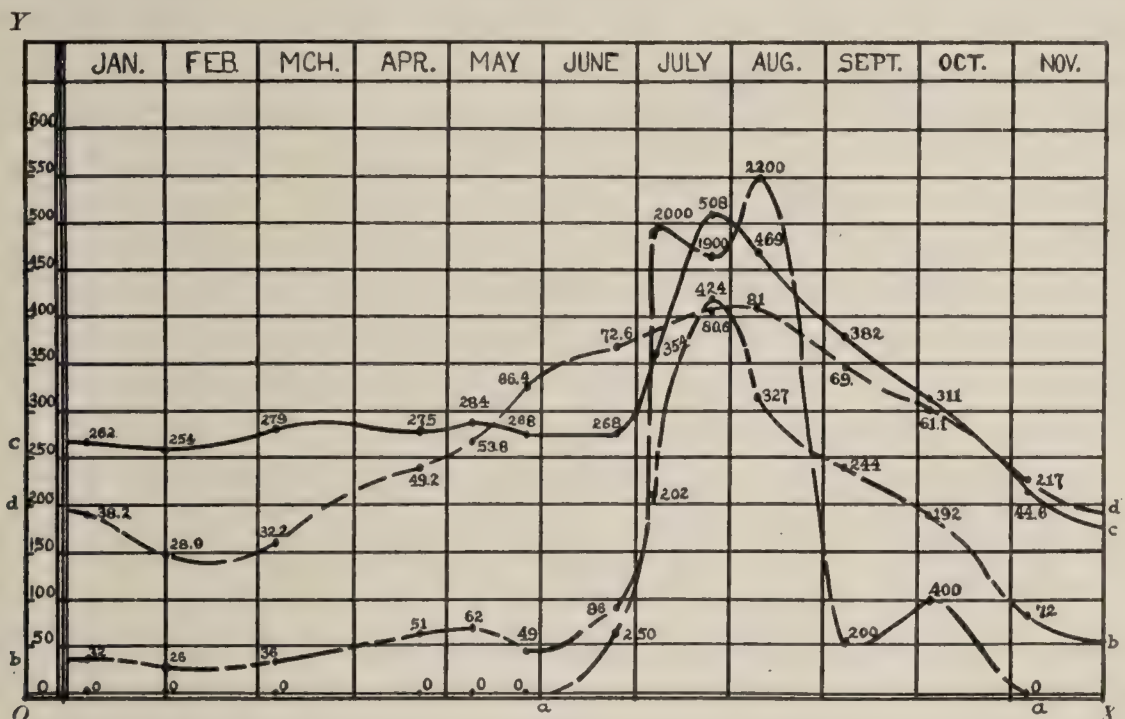

FIG. 83.—Infant mortality curve. *a*, prevalence of flies; *b*, diarrheals under five years; *c*, deaths under one year; *d*, mean temperature.

Scales

1 c.m. = 50 deaths	1 c.m. = 10 degrees
1 c.m. = 200 fly prevalence	1 c.m. = 15 days

locates a horizontal line. At the place of crossing of these two lines make another tiny cross. This cross indicates that there were 32 deaths of children under 5 years of age during the week of Jan. 4, 1908, in New York city. Next locate the vertical line representing Feb. 1 and the horizontal line valued at 26, and locate a second crossing point.

Continue in this way, and connect all the tiny checks made with an evenly curved line. This is called a "curve" and in this case might be called a "diarrheal curve." Now take the second line of data from the table and locate another curve.

(The various curves may be represented in different colored pencils, or by differently broken lines, as in Figure 83.) Locate the temperature curve in the same way. However, since the temperature numbers do not run so high, it is wise to allow a large square's distance on the vertical line OY, as representing 10 degrees. Thus continue to locate as many curves as is desired, taking care not to intermingle so many, however, as to make difficult reading.

Observation. — What months show the highest mean temperature? The greatest prevalence of flies? The highest death rate under one year? Five years?

Conclusions. — 1. What months have the most favorable temperature for the development of bacteria in milk? What extra care should be taken with the milk supply (*a*) when milking? (*b*) when in transit to customer? (*c*) when in hands of customer?

2. What does the "prevalence of flies" curve show (*a*) as to comparison with mean temperature? (*b*) prevalence of diarrheal diseases? (*c*) deaths under one year?

3. What special precautions should be observed by all and especially mothers with babies under five years as to (*a*) milk supply? (*b*) food of any description? (*c*) presence of flies?

4. Tell some of the ways by which you could aid in helping to reduce the terrible mortality of babies during the summer months, especially in the large cities. *Note.* — In 1908, 15,000 babies under one year of age died in New York city alone from improper preparation and care of food.

Method b. — Using the above as a model, refer to any mortality tables[1] you may be able to get and plot similar curves and write out any conclusions you may be able to make. Of course the most valuable one for your purposes would be from data furnished by your own local Department of Health. If such cannot be obtained, use those published by your State Department of Health, or of any other city or state.

[1] Such tables as given on p. 33, Bulletin Merchants' Association, New York, "The House Fly at the Bar," are good. Also study the curves plotted in the same bulletin.

Try to decide just how you would go at it in order to improve conditions, or show your neighbors who may not know as much about the matter as you have found out.

IV. OTHER MORTALITY CURVES (FOR ADVANCED STUDENTS)

Observations. — 1. Use monthly or yearly reports of the department of health from any source, as, for example, The Report of the New York City or New York State Departments of Health.

Try to plot curves as in the preceding section for other causes of death, as, for example, measles, scarlet fever, diphtheria, croup, meningitis, pneumonia, diarrheal diseases, congenital debility, etc.

2. Which sort of disease is most prevalent during the year? In summer? Winter? Spring? Autumn?

Conclusions. — 1. Try to account for the greater prevalence of certain diseases at certain times of the year. (Note temperature, food, milk, water, flies, exposure, sanitation, etc.)

2. What means would be most effective in reducing such death rates? Specify in detail for each particular disease.

3. Suggest how you might coöperate with the Board of Health.

4. Comment on the following statement: "Six hundred thousand infants under two years of age end their little span of life yearly, while millions of children fail to reach their best physical development because their mothers and fathers understood not how to care for them in the light of science — with more knowledge at least half the number of babies could be saved and the physical standard raised immeasurably." — *Household Education League.*

V. PREVENTION OF INFECTIOUS DISEASES

1. In section I we have learned

First: that disease germs come from the bodies of the sick in excreta, sputum, etc.;

Second : careless people are scattering germs about, so that they finally reach the bodies of the well.

2. It would therefore seem wise that, if we wish to prevent these germs from entering our bodies, we must

First : immediately destroy the germs that may be in the excreta of the sick ;

Second : prevent disease germs that are being scattered about carelessly from entering the body, as well as reduce the scattering as much as possible ; and also,

Third : develop in the body a power to fight these germs (*immunity*) if they should happen to enter the body.

a. Destroy Germs from the Sick

1. Disinfection of Sputum and Excreta

1. How have you learned germs may leave the bodies of the sick? (See section I.)

2. How have you learned such germs may be killed? (See Prob. XXIII, **c**). What have you learned concerning the value of heat, sunlight, drying, and certain chemicals such as corrosive sublimate, carbolic acid, lysol, and formalin? Chloride of lime, milk of lime, and cresol are also very good.

Note. — Any germ killers, such as those just named, are known as *disinfectants.*

The wastes from the bodies of the sick may be received in receptacles, and disinfected by adding an equal bulk of 5 % formalin, lysol, or corrosive sublimate. Let the waste matter stand several hours before disposing of it. Why?

3. If germs are from the nose or mouth, the sputum or mucus containing them should be received in small pasteboard cups, or a handkerchief. These should all be burned as soon as practicable. Carbolic acid or lysol may be added in case it is not convenient to burn them. *Under no circumstances* permit sputum from those diseased to dry. Why not?

2. Quarantine (Home)

Observations. — *Note.* To quarantine is to separate those suffering from contagious disease from the well. The sick are sent to hospitals or detained at home until well.

1. Why should houses with diseased inmates be placarded?

2. What benefit from permitting sunshine to enter the rooms of quarantined people?

3. Show why heavy curtains or carpets should not be allowed in the room.

4. Should clothing, carpets, etc., be taken from the room without boiling or disinfecting them? Explain.

5. Would it be well to sweep the room before the sick are removed? Explain. How should the room be dusted?

Conclusion. — Write a paragraph telling how to quarantine a person in a house.

Observations. — 1. Suggest how the room may be disinfected after the patient recovers. *Note.* — One of the best means is, first, to stop all cracks, etc., with wet paper. Put one pint of pure formalin in two quarts of water. Evaporate it with heat. Or, wring out cloths from the solution and hang them on lines in the warm room. Keep the room closed twelve hours, then open to fresh air and sunshine as much as possible for a day or so.

2. Why should one's hands be washed with soap and water after handling a patient or his clothes?

3. Why should a patient's body and hair be cleansed with soap and water after recovery?

Conclusion. — Write a paragraph telling how to disinfect a room and a person after quarantine.

3. Ship Quarantine (Ellis Island)

Observations. — 1. Why is New York city often called "America's Front Door"?

2. Why are incoming ships met in the harbor by a health officer?

3. Why are steerage passengers taken to Ellis Island and special inspections made?

Conclusion. — Write a paragraph telling how ship quarantine is of special value in destroying germs from the sick.

b. Prevent Germs from entering the Body

Considerations. — 1. Study Figure 84. Is there any good reason for keeping flies away from food?

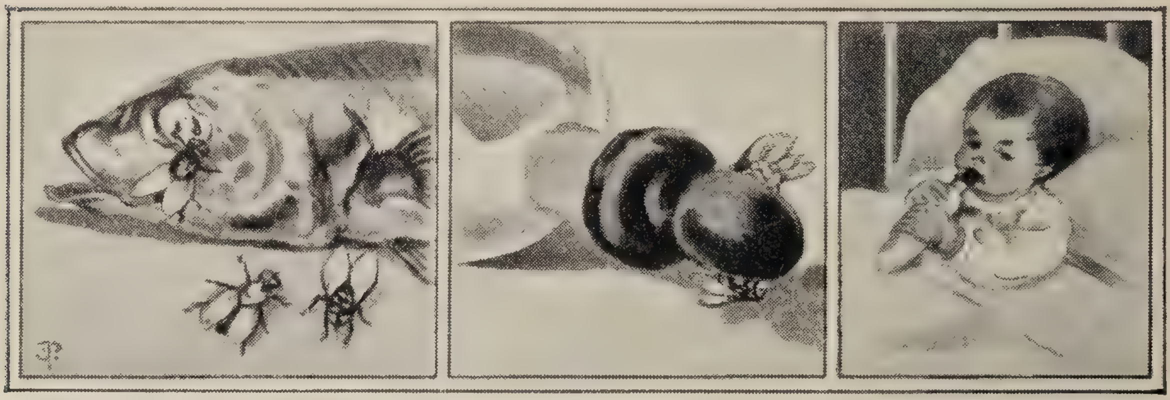

FIG. 84. — Showing how house flies carry disease germs from putrid matter to babies. (Courtesy of The American Civic Association.)

2. Why is the common fly called the 'typhoid fly'?

3. Explain the benefits of boiling and filtering water. Of pasteurizing milk.

4. Why should there be no such things as public drinking cups, towels, combs, etc.?

5. Why should we be especially careful and not permit ourselves to be bitten by such insects as mosquitoes, fleas, and bedbugs?

6. Explain just why sputum should not be permitted in public places.

7. What are the reasons for sewage disposal?

8. Why should railroads be especially careful in disposing of the wastes from the human body?

Conclusion. — Write a paragraph or two telling what you can of the different ways of preventing germs from entering our bodies.

c. Development of Immunity

Note. — Immunity is such a state of the body that disease germs are comparatively harmless. It depends on the power of the blood and other fluids of the body to kill germs.

Observations. — 1. Are there any advantages to the body because of plenty of fresh air, good food, rest, and exercise?

2. Review the functions of the white corpuscles of the blood.

3. What effect has alcohol on the white corpuscles?

4. What are antitoxins? *Note.* — An *antitoxin* is a substance that prevents poisons commonly developed in the body from the growth and action of disease germs from harming the body. They are given to prevent such diseases as diphtheria, rabies, etc. Name others.

5. How are antitoxins given? *Note.* — Whenever germs in antitoxin or vaccine are introduced into the body artificially, the person receiving the germs is said to be *inoculated.*

6. What is meant by vaccination? *Note.* — Smallpox, cholera, anthrax in cattle, and hydrophobia are being successfully fought by means of vaccination to-day.

7. Explain the modern treatment for consumption.

Conclusion. — Write a paragraph, summing up all you know as to the different means of bringing about immunity in the body.

d. Work of the Board of Health

"The greatest problem of the health official is the influential citizen who insists on his right to live like a hog, and be a menace and a nuisance to all his neighbors." — *An American Health Official.*

Note. — All citizens should obey their instructions implicitly and aid Health Boards to the best of their ability.

1. See that certain laws are enforced to prevent causes of sickness and spread of diseases. What diseases?

2. Placard all houses with contagious diseases, quarantine the inmates, and later disinfect the house. Why?

3. See that the garbage is buried or burned, and sewerage properly disposed of. Why?

4. Prevent the sale of unhealthful milk and foods. Why?

5. Provide for a supply of pure water. Why?

e. Health Creeds and Leagues

Observations. — 1. See if you can justify or condemn the following statements of Health Creeds: —

I

1. Eat moderately. Meat no more than once a day. Fletcherize.
2. Drink pure water. About 8 glasses a day, between meals. No water at meals.
3. Keep in fresh air as much as possible. Breathe deeply. If you cannot walk, at least bundle up and sit in the sun.
4. Plenty of fresh air in the sleeping room. Have sitting room window lowered at least one foot.
5. Bathe or wash every day in as cold water as one can well stand.
6. For adults, drink no milk.
7. Eat plenty of fat, to fight disease germs.
8. Have change of occupation.
9. Avoid intoxicants, which destroy the cells that fight disease germs.
10. Keep your temper.

II.

1. Eight hours' sleep.
2. Sleep on right side.
3. Keep bedroom window open all night.
4. Have no mat at bedroom door.
5. Bedstead not against wall.
6. Bathe in morning at body temperature.
7. Exercise before breakfast.
8. Eat little meat, and that well cooked.
9. For adults, drink no milk.
10. Eat plenty of fat.
11. Avoid intoxicants.
12. Daily exercise in open air.
13. No pet animals in living rooms.
14. Live in country, if you can.
15. Watch the three D's — drinking water, damp, and drains.

16. Have change of occupation.
17. Take frequent and short holidays.
18. Limit your ambitions.
19. Keep your temper.

— Sir James Sawyer.

2. Write to Dr. Irving Fisher, of Yale University, asking the address of your state secretary of the American Health League. Ask his aid in forming a local league.

3. Form a local league in your school. Model your platform something after the following: —

I AM A MEMBER OF THE

American Health League

HENCE, I believe in fresh air, sunshine, moderate eating of pure food, kind words, radiant cheer, and beautiful thoughts.

I believe in assisting in every way possible to spread the idea of public health, both in governmental and in personal functions — thereby prolonging life, increasing human endeavor, and making easy the pursuit of happiness.

— *Ben La Bree, Jr., Ohio Secretary of the League.*

4. On the basis that at any one moment there are at least 3,000,000 people in the United States seriously ill, half of which illness is preventable, will you write a letter to your Congressman, urging the establishment of a United States Bureau of Health? Study the following reasons and rewrite them in your own language: —

To stop the spread of typhoid fever through drinking sewage-polluted water of interstate streams.

To enforce adequate quarantine regulations, so as to keep out of the country plague and other similar pestilences.

To supervise interstate common carriers, in so far as without such supervision they prove a menace to the health of the traveling public.

To have a central organization of such dignity and importance that departments of health of states and cities will seek its coöperation.

To influence health authorities, state and municipal, to enact uniform legislation in relation to health matters.

To act as a clearing house of state and local health regulations and to codify such regulations.

To draw up a model scheme of sanitary legislation for the assistance of state and municipal health officers.

To gather accurate data on all questions of sanitation throughout the United States.

To reduce the death rate.

Questions

1. Why should dish cloths and towels be frequently scalded and sun-dried?

2. Why should individual combs, towels, brushes, and drinking cups be used?

3. Why should all fruits exposed for sale be kept covered?

4. Why are oranges and bananas safer fruits when bought from a street vender than such fruits as apples, grapes, and pears?

5. Why is the common practice of dusting clothing in a Pullman car a dangerous one?

6. Why are the so-called tourists' sleepers more sanitary than the ordinary Pullmans?

7. Refrigerators should be frequently scalded out and washed with some antiseptic, as washing soda. Explain.

8. Give one sanitary reason for cooking foods.

9. Why should fruits eaten raw or with the skins be thoroughly cleansed?

10. What clothes most need the laundry, from the standpoint of health?

11. Why are there more intestinal troubles contracted in summer than in winter, while riding on railroad trains?

12. What is one of the important uses of hydrogen peroxide?

13. Why should city streets be flushed with an antiseptic water, instead of being swept? (Chlorine water is good.)

14. Why should *there be a United States Bureau of Health?*

15. "It is within the power of man to cause all parasitic diseases to disappear from the world."—PASTEUR. Comment on this statement.

Special Reports

1. The great white plague.
2. What health is worth to us.
3. Personal hygiene.
4. Civics and health.
5. Health creeds.
6. The American Health League.
7. Quarantine.
8. Principles of sanitation.
9. Boards of health.
10. The development of immunity.
11. The life and work of Pasteur.
12. The bubonic plague.
13. Bacteria in daily life.

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SUMMARY VII

A summary of the causes and prevention of disease — personal and civic hygiene.

I. THE CAUSES OF DISEASE

1. The work of parasites. (But one in forty die of old age.) Bacteria mostly.
   a. Infectious.
      (1) Contagious.

(*a*) Consumption.
(*b*) Smallpox.
(*c*) Scarlet fever.
(2) Noncontagious.
(*a*) Yellow fever.
(*b*) Lockjaw.
(*c*) Typhoid.
(*d*) Malaria.
b. Noninfectious.
(1) Alcoholism.
(2) Diabetes.
(3) Insanity.
(4) Cancer.

2. How germs enter the body.
   a. Breathing.
   b. Drinking cups.
   c. Pencils, fingers on books, etc.
   d. Food.

3. How tuberculosis may enter the body.
   a. With food or milk, — through walls of the intestine, thence to lungs in the blood.
   b. With the air.

4. How typhoid germs enter the body.
   a. With food.
   b. By flies on food.
   c. Milk.
   d. With water. Surface waters in shallow wells.

5. Alcohol.
   a. Weakens cells that fight disease.
   b. Causes diseases of liver, kidneys, and heart.

II. PREVENTION OF DISEASE

Note. — Over 100,000 people lose their lives yearly by reason of germs.

1. Destroy germs by:
   a. Boiling excreta from bowels and kidneys of persons suffering from contagious diseases.
   b. Adding 4% solution of formalin to excreta of the above.
   c. Putting the sputum of the sick in a cloth, or in boxes, and burn.
   d. Killing off the flies.
   e. Quarantine.

f. Disinfecting rooms with 1% carbolic acid, sunlight, and formalin.
g. Disinfecting persons and their clothing.

2. Stop germs from entering the body by:
   a. Keeping flies away from food.
   b. Drinking from clean vessels, — pasteurize them as well as the milk and water.
   c. Keeping off mosquitoes, fleas, and bedbugs.
   d. Burning the sputum from patients.
   e. Filtering the water
   f. Disposing of sewage.
   g. Avoiding alcohol.
   h. Using individual drinking cups at public drinking places.
3. Develop in the body a substance which kills harmful germs by:
   a. Good food, rest, air, exercise, and sunlight.
   b. Antitoxins, — as against diphtheria, etc.
   c. Vaccines, for smallpox, hydrophobia, etc.

SUMMARY VIII

A summary of some biological processes in organisms, with special reference to reproduction, heredity, and hygiene.

a. The Flower

Considerations. — 1. What is the principal reason for the existence of any flower?

2. What is produced by a complete flower?

3. What is the function of pollen? Of ovules? Of stamens? Of pistils?

4. Explain Figure 85. What does it show?

Note. — The cell in the pollen grain which grows into the pollen tube is known as the *sperm cell.* The cell in the ovule which fuses with the sperm cell is called the *egg.* When these fuse they form a single cell, — the fertilized egg. The egg immediately begins to develop (see Prob. XXVI, **a**), to form a minute prophecy of the future plant, which is called the *embryo.* This stops growing when the seed is ripe, in zones with a winter climate or a dry season, to again grow and develop when proper conditions of temperature and moisture are present.

Conclusions. — 1. Does there seem to be any reason for the fusion of the sperm cell with the egg? *Note.* — The two cells being different, may it be the case that each cell supplies the other with something that it lacks?

2. Study Figure 86. Note that the end of the pollen tube containing the sperm cell is about to unite with the egg.

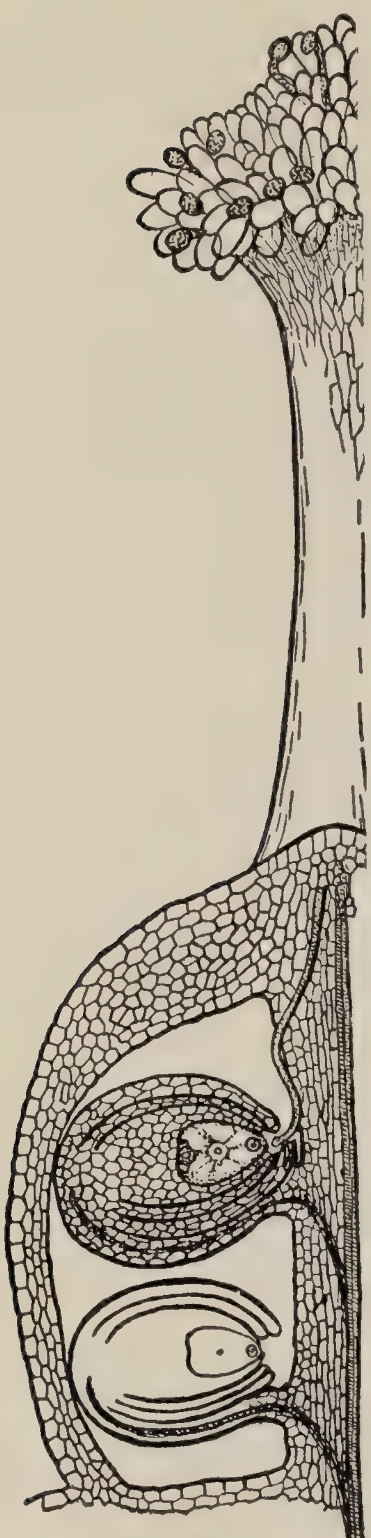

FIG. 85. — Diagram showing how the ovule is fertilized. The pollen tubes sprout and grow in the sweet liquid on the stigma, passing through the stigma and style and finally entering the cavity of the ovary through the micropyle.

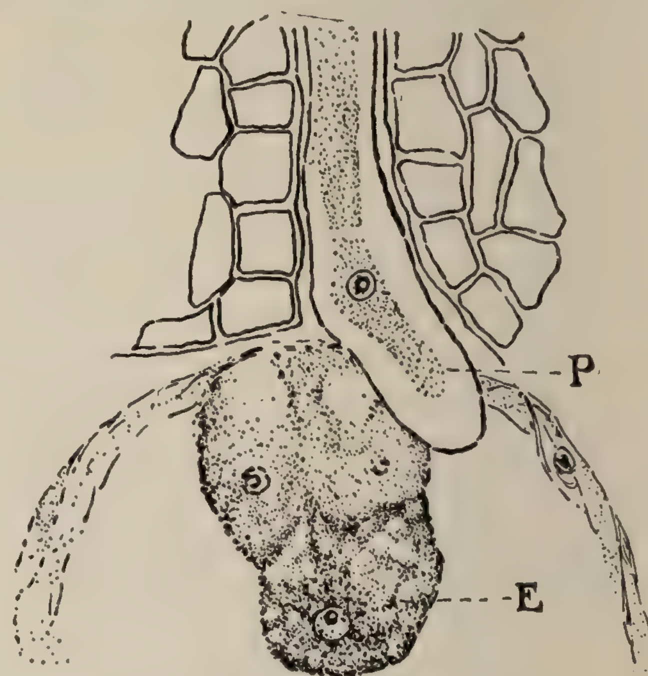

FIG. 86. — Showing beginning stage of fusion of germ cells in cotton plant. (After Duggar.) *P*, pollen tube passing through the micropyle, and carrying a single sperm cell. *E*, egg.

Note. — The sperm cell is thought to furnish the egg cell with a renewal of vigor, so that it will now actively develop to a mature plant. Otherwise it would stop, after reaching the period of growth represented by its condition in the ovule before fertilization.

b. Protozoa

Considerations. — 1. What is the simplest method of reproduction in such a simple-celled animal as a paramœcium?

2. Will this method suffice for any length of time?

3. What must happen to prevent the species from dying out? *Note.* — Conjugation is a term which may be used to denote either a *temporary* or *permanent* fusion with another individual.

4. Find out just what happens when conjugation takes place. (Study charts or Figures or text.)

Conclusions. — 1. Does there seem to be any reason why reproduction does not go on indefinitely by simple division?

Note. — "A freshening by the introduction of new vigor seems to be necessary from time to time." — Hæckel.

2. Then why should Protozoa conjugate, or "trade experiences"? *Note.* — In conjugation of paramœcia the traveling nuclei serve as *male* traveling nuclei, while the nuclei remaining serve as *female* standing nuclei. When the fresh nuclei have been formed, they separate. The two new rejuvenated cells have once more acquired the power of renewed activity and also of the ability to propagate by division for a time, or until this power is exhausted, when conjugation must again take place.

c. Metazoa

1. Fish

Observations. — 1. Procure some fresh milt (sperm) of any fish most conveniently at hand, as from the nearest state or government fish hatchery. Also get some unfertilized eggs freshly "stripped" from the body of the female. Place some of the unfertilized eggs in a clean bowl, as a glass finger bowl, and pour over them some of the milt or sperm. Set the bowl aside in a moderate temperature. (This is known as artificial fertilization.) Which are evidently the larger, sperm or eggs? Which are the most motile? (Examine some with a compound microscope.)

2. Place another lot of eggs in another bowl, and set aside with the first lot, but unfertilized.

3. Watch both lots for a few days. Which evidently increase in size?

4. Has fertilization evidently taken place in one lot? Explain your answer. *Note.* — In nature the ova (spawn or eggs) of fishes are usually deposited in the water in various hidden places on the bottom. The milt or sperm is poured over them by the male, and the eggs are left to develop with little or no care.

5. Do you think that such habits would result in much care of the young?

6. *Note.* — The eggs of most sharks and such fishes are retained within the body of the mother until they are hatched.

7. Why should eggs be deposited in large numbers when they are laid in the water?

8. Why are eggs fewer in number when they are fertilized within the body of the mother, and afterwards laid?

Conclusions. — 1. Should you think there would likely be more or fewer eggs if they are not only fertilized within the body of the mother, but also hatched there?

2. Explain whether better care is shown when eggs are deposited in the water to be fertilized and hatched, or when such processes take place within the body of the mother.

3. Which should be the larger because of contained food, — eggs that are laid, or those that are hatched within the body of the mother? *Note.* — When any young are hatched within the body of the mother, they soon use up the food yolk of the egg, and thereupon develop a special set of blood tubes connecting with those of the mother, through which they get their food supply.

2. Birds

Observations. — 1. Break a hen's egg into a saucer. Note a small circular spot somewhat different from the yolk in color. *Note.* — This is the so-called germinal layer, and locates the real tiny egg. The yolk and the white constitute food for the growing embryo.

2. Has the embryo evidently developed much by the time the egg was laid?

3. Since the fertilized egg cells of birds are deposited outside of the body, can you see any reason for a shell?

4. Why would it not be well that birds lay their eggs before the eggs are fertilized? Do such animals as fishes and frogs lay eggs with shells? Where are the eggs laid, and in what numbers?

5. Compare the ovary of a bird with that of a flower. What likenesses do you find? What differences?

Conclusions. — 1. What are the main differences in the process of fertilization of a bird's egg and the egg in the ovule of the lily? *Note.* — The sperm cell of the male bird is very minute and is provided with a lash to whip itself along.

2. Why are eggs necessarily larger than sperm? Which most readily admit of independent movement, sperm or egg? *Note.* — We here find a fine example of physiological division of labor; on the one hand conjugating cells must be very motile and consequently minute, so that they may meet in such a liquid as water, where they are commonly liberated (examples: water plants, ferns and mosses, frogs and most fishes, etc.); and on the other hand, they must be so supplied with food that the young embryo may be provided for until it is able to shift for itself. These two requirements are here evidently met by a physiological division of labor between the two conjugating cells. One cell, called for convenience the

sperm cell, is much reduced in size so as to be correspondingly very active and motile; while the other, called the egg, has the food yolk stored up in it, with a consequent increased size, which prevents more than very slight independent movement, if any.

3. Can you distinguish between sexes among Paramœcia? Lilies?

Note. — Along with differences between the sexes for purposes of division of labor, such as noted above, we note other secondary differences between them creeping in, so that we may readily recognize male and female individuals. We readily distinguish a male bird from a hen. Note the differences between a peacock and a peahen. Give other examples among higher animals.

3. Various Means used by Sperm Cells in reaching Eggs (Optional)

Observation. — Fill in the following tabulation, wherever possible: —

Method	Examples	
	Plants	Animals
Conjugation		
Ciliated cells in water		
Pollen and wind		
Pollen and closed flowers		
Pollen and insects		
Motile pollen		
Archegonium and motile sperm as of fern		
Pistil or pollen type		
Body tubes of Metazoa		
Artificial means		

d. Heredity

"Nature loves variety, so that the best will survive. She has never yet made two eggs or two sperm cells exactly alike." — Jordan.

Observations. — 1. It is matter of common observation that individuals are much like their parents. Children inherit race characteristics, and the young of roses are the same sort of roses, of salmon the same sort of salmon, and of Indians the same sort of Indians. We all agree that a rose does not produce a fern, or a fish a frog.

2. It is also a matter of common observation that individual peculiarities and deficiencies suffice to distinguish one rose, or fish, or person from another. Did you ever know two persons having the same color of eyes, hair, and skin ; the same form of nose and ears, character of thumb prints, etc. ?

Conclusions. — 1. If the above observations are true, where have these peculiarities originated ? Do children or offspring commonly show traits of both parents ?

2. If so, how must these traits have been transmitted to the embryo ? Must they not have existed in the germ or sex cells ?

Observations. — 1. Could the Arab raise swift horses if he had constantly mixed draft horses in the herd ?

2. Could Mr. Burbank produce fine fruits by mixing various plants indiscriminately ? *Note.* — The fine work of the horticulturist depends on selection and fixing of variations produced by cross fertilization between rather closely allied plants.

3. What do you imagine might be the characteristics of a fruit resulting from the pollen of the plum being allowed to fertilize the ovules of the apricot ? *Note.* — Mr. Burbank has succeeded in producing such a fruit as would result from this process, called the *plumcot.* Such fruits are not always permanent, however, as they tend to revert (go back) to one or the other type.

4. What do you imagine might commonly be the result if a weak, sickly plant or animal should be crossed with another which might even be quite healthy ? *Note.* — Culled sheep, feeble, loose-jointed, and otherwise very poor in quality, have been bred, resulting in producing a still worse type of sheep, although it could be clearly seen they were Hampshire sheep.

Conclusions. — 1. What is necessary in order to improve races and stocks ? Would it do to select poor parents ?

2. Why do farmers select the best ears of corn for seed ? What is the real reason ?

3. How are fast trotters developed by horse breeders ?

4. A man remarked : "I have drunk whisky every day for thirty-five years, and I don't see but what I have as good a constitution as the average man of my age. I was never drunk in my life." His eldest child had perfect health, the second was of a remarkably nervous temperament,

while the third, a young lady of seventeen, was epileptic and had always had poor health. May the father's habits have had anything to do with these facts?

5. Can you think of any instances where families have a tendency to gout, consumption, or epilepsy? Is there any noticeable effect on the children?

Note. — While these diseases may not be inherited, yet it is no longer doubted that the tendency to acquire them, or a weakness in such respects, may be transmitted.

6. What general conclusions can you make concerning the necessity of good general health of future fathers and mothers, either plant or animal?

e. Hygiene

Note. — Since the inheritance of vigorous qualities of father or both parents may be impaired or totally destroyed, it would seem wise to consider how such qualities may be kept at their best, for the happiness of individuals and the good of the race.

Considerations. — 1. What conditions lower the vitality of the body?

2. What habits are injurious to the body?

3. Name some germ diseases that are very harmful to the race. *Note.* — Some germ diseases are especially difficult to fight, particularly those producing blood poison.

4. How may disease germs enter the body? (See Prob. LVI, I.) *Note.* — Any opening in the body, or even a break in the skin, may permit the entrance of most deadly germs.

5. What might happen to the egg if disease germs should be carried to it with a growing pollen tube?

Conclusions. — 1. What part of a flower would be most probably seriously injured by bacteria should they attack it? Explain. *Note.* — The sexual organs of all forms of life are very delicate, more so than even the eyes, ears, and nostrils.

2. Why should all living things exert great protective oversight of anything concerning the future of the race?

3. Is it wise to use public drinking cups, towels, napkins, etc.? Explain.

4. Even if germ cells are not killed by the action of bacteria, their future development will be most certainly seriously crippled. Many cases of idiocy, insanity, epilepsy, etc., are undoubtedly due to diseased germ cells.

5. Study the reports in the monthly bulletins of the new State Department of Health. What do you conclude regarding the prevalence of

disease germs? Explain why great caution should be exerted in using public wash basins, bedding, unclean hands, knives, forks, pencils, pipes, etc.

6. Should any form of life be permitted to reproduce its kind, if there is any likelihood of either parent being diseased? Explain.

7. Show how a large percentage of blindness may be produced before birth.

8. Write a paragraph on the necessity of proper food, exercise, rest, and recreation, especially with reference to heredity.

Questions

1. What is the purpose of food yolk in eggs?
2. Why does President D. S. Jordan say, "Nature loves variety"?
3. Upon what does the fine work of the horticulturist depend?
4. What has Mr. Burbank done for mankind?
5. What precautions are exerted by farmers in selecting seeds?
6. What is meant by heredity?
7. How may disease germs enter the body?
8. Why is the subject of heredity of so much importance?
9. Why are children's games that require contact of hands very dangerous?
10. What is one of the most common causes of blindness?
11. Show how it is dangerous for one to handle the eyes, ears, nose, or other sensitive organs of the body.
12. What is likely to be the effect of the use of alcohol as a beverage by parents on their children?
13. Tell of the great importance of controlling mind and body.
14. What have good thoughts to do with good health?
15. Explain meaning of the following: "The great perpetual battle of life is the warfare waged against self."

Special Reports

1. The everyday things one does to shorten life.
2. Scientific living, or the prolongation of human life.
3. Sleeping outdoors for health.
4. The importance of good thoughts, food, and exercise.
5. The occupation and rest cure.
6. National vitality.
7. The greatest social evil.
8. Hygiene and morality.

9. Explain and make a special report upon the following: —

"Thousands of homes are wrecked, tens of thousands of lives are ruined, and hundreds of thousands are made unhappy because the home-keepers of our country have no training in the greatest of all professions, the 'profession of home making and motherhood.' Only through such education can present domestic difficulties be solved, and the modern home contribute all that it should to happiness and well-being."

— *Household Education League.*

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SUMMARY IX

A summary of procedure in case of accidents and emergencies.

Note. — About 10,000 people annually die for lack of quick aid. The first half hour is the most important.

1. **Fainting.**
   Lay the patient flat on the floor. Admit plenty of fresh air. Sprinkle cold water on the face. Give hot milk or water.

2. **Intoxication.**
   Empty the patient's stomach by giving a tablespoonful of mustard in warm water. Follow with two or three cups of strong coffee and put him to bed.

3. **Fits.**
   No effective remedy. Keep the patient from injuring himself. Put a handkerchief between his teeth to prevent him from biting his tongue.

4. **Convulsions.**
   Put the patient's feet and legs in hot water, and apply cold water to his forehead. Give a dose of a cathartic.

5. **Sunstroke.**
   Apply cold water on head, neck, and chest, and give "ice pack." Why?

6. **Heat Exhaustion.**
   Give the patient hot coffee, and put him to bed.

7. **Suffocation.**
   Fresh air and artificial respiration. Friction and hot coffee.

8. **Clothing on fire.**
   Wrap the patient in a coat or a blanket. Roll him over and over on the ground. Apply a dilute solution of soda, and smear vaseline over the burns. Get a physician at once.

9. **Burns or Scalds.**
   By means of cloths, apply carron oil (1 pint of limewater added to 1 pint of linseed oil shaken), vaseline, kerosene, and soda solution.
   If burned with acids, use soda; if with alkalies, use vinegar.

10. **Frostbite.**
Rub the parts with snow or ice water, in a cold room till they tingle; then in a warm room.

11. **Cuts and Nail Punctures.**
Cause the wound to bleed freely. Wash it with turpentine, or 5% solution of carbolic acid. Bind it with clean cotton.

12. **Bruises.**
Apply a cloth wrung out of hot water, changed every two or three minutes, or use cold water as above.

13. **Nosebleed.**
Throw the head back, put broken ice to the back of the neck. Close the nose and breathe through the mouth.

14. **Choking.**
Strike the patient between shoulder blades, with his head down. Have him eat bread and potatoes to surround jagged object causing the choking.

15. **Poison Bites and Stings.**
Apply a tourniquet between the wound and the heart. Cut the wound and cause it to bleed freely. Apply crystals of permanganate of potash. Give whisky to keep up the heart action. Bathe stings in dilute ammonia or soda solution.

16. **General Poisons.** (8000 deaths annually.)
Give the patient an emetic of two tablespoonfuls of table salt in a glass of warm water, or a pint of warm water, or tickle his throat with a feather.

17. **Special Poisons.**

a. Carbolic Acid.
Give a tablespoonful of Epsom salts in glass of warm water, then a pint or so of milk, then a cup of coffee.

b. Ammonia or Potash.
Lemon juice or weak vinegar.

c. Arsenic.
Give the patient an emetic, and then olive oil.

d. Poisonous Plants when Eaten.
Emetic, then Epsom salts.

e. Poison Ivy.
Wash at once with soapsuds. Apply cloth soaked in equal parts of alcohol and water, with as much sugar of lead as will dissolve in it.

18. **Sprains and Strains.**
    Immerse the part in hot water or cold water, changed often. Massage a joint by rubbing toward the heart. *Carefully* exercise it unless the ligaments are torn.

19. **Particles in Eye.**
    Look down and turn the eyelid back over a pencil. Bathe the eyes in weak boracic acid.

A. **List of common medicines every family should own**, especially when not within ready reach of a physician : —

1. Bottle of mustard.
2. Carron oil.
3. Baking soda.
4. Vinegar.
5. Turpentine.
6. 4 % carbolic acid.
7. Roll of antiseptic cotton.
8. Roll of antiseptic linen.
9. Permanganate of potash.
10. Ammonia.
11. Boracic acid.

B. **Contents of an emergency case : —**

1. Cold cream.
2. 1 yd. cheese cloth.
3. Roll of adhesive tape.
4. Bicarbonate of soda.
5. Boracic acid.
6. Seidlitz powder.
7. Absorbent cotton.
8. 1 oz. bottle of : —
   a. Peroxide of hydrogen.
   b. Ammonia.
   c. Tincture of iodine.
   d. Spirits of camphor.
   e. Essence of peppermint.
9. Card of safety pins.
10. Pair of scissors.

Special Topics

Using the above topics as subject matter, ask the pupils to explain just why any particular procedure is valuable in any particular case. Try to get the "reason why."

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